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CONTENTS

		PAGE
N. W. SIMMONDS	*The Growth of Post-war West Indian Banana Trades* ..	79
SH. SMIRIN	*Banana Growing in Israel*	87
D. B. MURRAY	*The Effect of Deficiencies of the Major Nutrients on Growth and Leaf Analysis of the Banana*	97
D. PRICE	*The Control of Parasitic Eelworms in Bananas*	107
L. B. THROWER	*Observations on the Diseases of Cacao Pods in Papua–New Guinea—I. Fungi Associated with Mature Pods*	111
L. B. THROWER	*Observations on the Diseases of Cacao Pods in Papua–New Guinea—II. Cherelle Wilt*	121
D. H. LAYCOCK	*A Progress Report on the First Six Years of a Pruning Experiment with Nyasaland Tea*	125
D. H. ROMNEY	*Productivity of Pasture in British Honduras—I. Natural Pasture*	135
G. W. IVENS	*The Effects of Arboricides on East African Trees and Shrubs —IV.* Tarchonanthus camphoratus *L. and* Euclea divinorum *Hiern.*	143
BOOK REVIEWS		153
OBITUARY		160
RECENT PUBLICATIONS		162

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Vol. XXVIII. No. 109 CONTENTS January, 1960

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The Growth of Post-war West Indian Banana Trades

N. W. Simmonds

Regional Research Centre, Imperial College of Tropical Agriculture, Trinidad

The early phases of development of a banana trade are difficult for shipper and planter alike. Fruit can only be shipped economically in big units of many thousands of stems but the collection and despatch must be frequent enough that fruit is not lost in the field because immature at one cutting and over-mature at the next. A cutting cycle of 14 days is about the upper limit; seven to ten days is much better. This means that there is a minimum volume of production for economic operation and, until a young trade achieves this volume, the position of both planter and shipper is precarious; the planter may not feel like planting a crop whose economic future is uncertain, while the shipper may be running very close to his economic margin. It would obviously be of advantage to make this early period of growth as short as possible and there is therefore considerable incentive to achieve high early growth rates of new banana trades. Though this conclusion is generally accepted, there appear to exist no satisfactory data on how fast, in fact, banana populations grow. It is the purpose of this paper to present some data bearing on the point.

GENERAL REMARKS

Jamaica, alone of the British West Indian islands, has a long history of banana production, going back to the 1860s. Some of the other islands (Dominica, St Lucia, St Vincent, Grenada and Trinidad) had short histories of export production for the Canadian market during the 1930s. All these trades were based on the 'Gros Michel' banana and, at the start of the 1939–45 war, were suffering severely from the effects of Panama disease. The trades ceased during the war and Jamaica alone resumed the export of 'Gros Michel' in the immediate post-war years, as soon as shipping was available. However, Panama disease forbade any major re-development with this clone and considerable effort was put into the exploration of the resistant Cavendish group as a possible source of a new export clone, a search which ultimately proved successful. Similarly, the post-war trades built up in the other islands have also been based on members of the Cavendish group. Jamaica has, however, maintained a small (but declining) export of 'Gros Michel', now almost all produced by peasant cultivators in remote, hilly parts of the country.

All the four main Cavendish-type bananas are involved in the existing West Indian trades [for a review of the group see Simmonds (1959), pp 79–84]. Jamaica grows the tallest member of the group, 'Lacatan',

together with a small admixture of ' Robusta '. The Windward Islands (Dominica, St Lucia, St Vincent and Grenada) grow ' Robusta ' with some admixture of ' Lacatan '; Trinidad grows a mixture of all four of the principal clones, ' Dwarf Cavendish ', ' Giant Cavendish ', ' Robusta ' and ' Lacatan ', of which the last two named probably predominate. The plant populations by which the export fruit is produced have been developed from various sources. Jamaica, building on trials which had been started before the war, expanded her ' Lacatan ' populations from internal sources, the clone having been originally brought to the island from the Far East many years previously. Dominica also developed an existing population, in this instance of the ' Porto Rique ' banana, which subsequently turned out to be ' Robusta '. St Lucia imported considerable quantities of suckers from Guadeloupe, whose trade is based primarily upon ' Poyo ' (= ' Robusta '), and was later an important source of ' Robusta ' stocks for St Vincent and Grenada. In Trinidad, a combination of importation of suckers and bulking up of existing stocks was used.

There are considerable economic differences between the banana trades of the different islands. In Jamaica fruit is sold by the ' count ' or ' bunch ' and the affairs of the industry are managed by a statutory body, the Banana Board, which makes all the necessary arrangements with the shipping companies. In the Windward Islands, by contrast, fruit is sold by weight (subject to a fluctuating minimum grade and weight per stem) and collection, shipping and marketing are handled by one company for the islands collectively, the growers' interests being represented, where necessary, by Banana Growers' Associations. In Trinidad, fruit is also bought by weight rather than by grade; it is all shipped by one company (which also grows a significant proportion of the export crop); such necessary functions as collecting the small farmers' fruit, issuing cutting notices and so forth are carried out by the Government Marketing Board. An important result of the differences between Jamaica and the other islands in respect of the methods of purchase of fruit is that Jamaican planters must aim to produce comparatively few stems of high grade per acre whereas planters in the other islands can adopt closer planting and other agricultural practices aimed at producing high yields of fruit per acre regardless of grade.

One would expect that, as a result, Jamaican bunch weights would be higher than in the other islands. In fact this is not so, for Jamaica and the Windward Islands all average about 30 pounds per bunch. The reason is that Jamaican bananas are grown on soils of very varying quality derived from sedimentary rocks whereas, in the Windwards, the plants are grown on volcanic soils that, if properly managed, are ideally suited to the cultivation. Furthermore, the Windwards' crop is quicker to mature and is less liable to growth checks caused by drought and low temperatures. The result is that they have a similar average bunch weight to that of Jamaica and higher gross yields per acre.

Jamaican bananas are predominantly grown in pure stands, though the practice of combining coconuts with banana cultivation seems to be increasing. In the Windward Islands and Trinidad, by contrast, bananas are often grown in mixed stands, either under coconuts (as in St Lucia) or in combination with cocoa (as in Grenada and Trinidad).

THE GROWTH OF THE TRADES

Production data (as stems exported per annum) for the 12 years 1947–58 are given in *Table 1*. It will be seen that the six trades represented started at various times from 1947 until 1954 and that the total production in 1958 was 15 million stems.

It is proposed to use these data to give an indication of the underlying changes in plant population in the various islands. The ratio of production to population probably varies from place to place, being higher in the Windward Islands (with volcanic soils and equable climates) than in Jamaica (with less favourable soils and a distinct winter growth check); but there is no reason to suspect that it varies significantly in time for any one island except when catastrophically (and obviously) affected by a hurricane or (less obviously) by large-scale sucker importation or by the use of nurseries for sucker production. For the present we will assume that the ratio is constant within an island, whence it appears that production data may be used to estimate population growth rates (whether measured as annual rates of multiplication or as relative growth rates). If a and b are production data for two successive years and x is the production/population ratio, the two measures in question are

$$\frac{xb}{xa}=\frac{b}{a} \text{ and } \frac{xb-xa}{xa}=\frac{b-a}{a}$$

In short, production data may be treated as population data for the purpose of assessing and comparing growth rates.

The rate of growth of a banana population depends upon the capacity for suckering (which is characteristic of a clone) and upon external factors such as management, water supply and soil. Jamaican investigations of the ' Lacatan ' banana suggest that, in the nursery, annual rates of multiplication of about ten can be achieved whereas, by combining fruit and sucker production, the annual rate of multiplication falls to about five. These are rounded figures which might be expected to vary with locality and clone but they will serve to indicate the order of size of potential rates of increase [for details see Various Authors (1951, 1952, 1954); and review by SIMMONDS (1959) pp 194–9]. For the present purpose, we will take the figure five as an indication of the annual rate of multiplication that may be expected when fruit and sucker production are combined in commercial fields.

Whatever the actual size of the factor of increase, we should expect the population to grow geometrically, for a few years at least. This situation may be described thus

$$F=F_0m^t$$

where F is population at time t, F_0 is the initial population at time t_0 and m is a constant, the annual rate of multiplication. Since

$$\log F=\log F_0+t.\log m$$

we have the well known result that, if increase is geometrical, log F plotted against t will give a straight line of gradient log m.

The data of *Table 1* are plotted logarithmically in *Figures 1* to *6*. St Vincent shows a reasonably close approximation to geometric increase in the early years. St Lucia and Jamaica both had short periods when the lines were nearly straight; the data for Grenada were disturbed by a hurricane; for Dominica and Trinidad there is no approach to linearity.

Table 1. The development of six West Indian banana trades; annual exports in thousands of stems

(H—hurricane; D—drought)

	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
Jamaica	2	26	120	460	796H	2 616	5 714	7 948	8 569	11 216	10 011D	9 814
Dominica	7	15	121	350	577	857	1 136	1 352	1 374D	1 790	1 404D	1 689
St Lucia	—	—	—	—	18	56	143	300	456H	794	974	1 151
St Vincent	—	—	—	—	—	—	—	36	118	342	1 205	1 485
Grenada	—	—	—	—	—	—	30	103	92H	67	569	943
Trinidad	—	—	—	—	—	—	—	—	91	214	296	327
Totals	9	41	241	810	1 391	3 529	7 023	9 739	10 700	14 423	14 459	15 409

Table 2. The growth of six West Indian banana trades

Place	*Age (years)*	*Observed* m_{1-2}	*Observed* m_{2-3}	*Interpolated* m_{1-3}	*Years to first decline*	*1958 production (rounded)*	*Extrapolated limit (years)*
Jamaica	12	13·0	4·6	(4·7)	4–5	9 800	10 500 (1959)
Dominica	12	2·1	8·1	(4·9)	3–4	1 700	1 700 (1959)
St Lucia	8	3·1	2·6	2·8	2–3	1 200	1 200 (1959)
St Vincent	5	3·3	2·9	3·2	4–5	1 500	3 800 (1963)*
Grenada	6	3·4	(H)	2·9	2–3	940	1 700 (1963)*
Trinidad	4	2·4	1·4	1·9	2–3	330	350 (1959)

* These are reasonable figures for estimates that may vary within very wide limits. For St Vincent, estimates lie between 2 and 6 million in 1961–3, for Grenada between 1·5 and 2·2 million in 1962–3.

Estimates of growth rates are given in *Table 2* as annual rates of multiplication of population (columns 3 to 5): m_{1-2} is the ratio of exports in the second year to those in the first, m_{2-3} the same ratio for the second and third years. In column 5 (m_{1-3}) are given mean coefficients of increase for the two intervals computed by drawing smooth curves and calculating the factors from them. With two exceptions, every estimate of m is less than five, and four out of the six islands never even achieved an annual rate of multiplication as high as four. The two exceptions are provided by Jamaica and Dominica. For the former the exceptionally high value of m_{1-2} (=13·0) was undoubtedly caused by extensive nursery production of suckers. For Dominica, m_{2-3} =8·1 and for this neither nursery production nor importation of suckers was responsible. The increase was achieved solely by development of an existing population of scattered and non-productive plants; in other words m_{2-3} was high because F_2 was low in relation to plant population rather than because F_3 was high. For these two islands, Jamaica and Dominica, the curves are correspondingly irregular in the early stages and the interpolated values of m_{1-3} (given in parentheses in *Table 2*) are therefore of somewhat doubtful significance, though they do serve to indicate the comparatively high overall rates of multiplication achieved in comparison with the other islands.

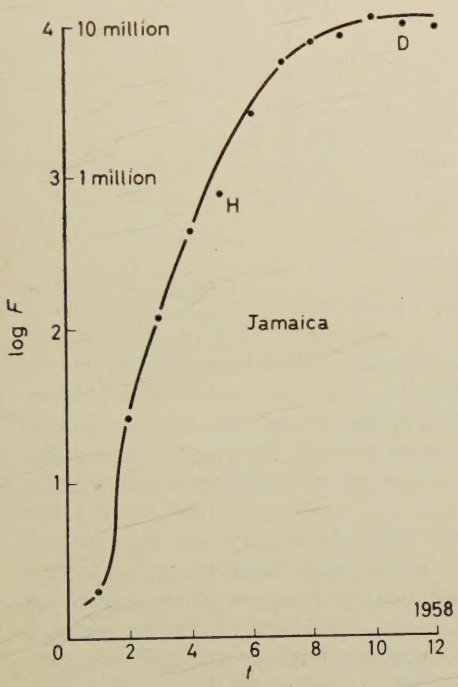

Figure 1

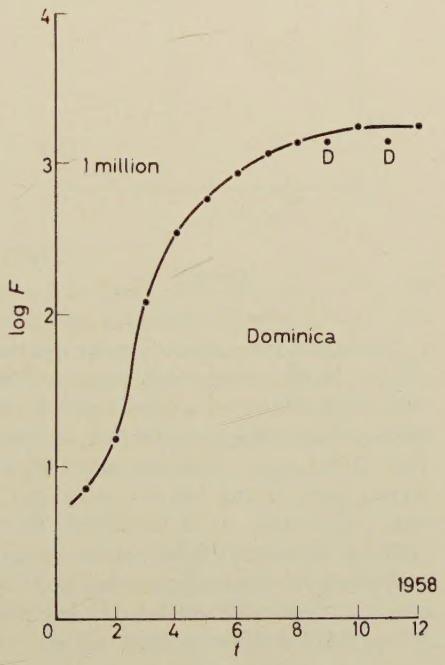

Figure 2

Column 6 of *Table 2* shows that there was a perceptible slowing down of growth (as indicated by the curvature of the graph) in every trade after, at most, four years.

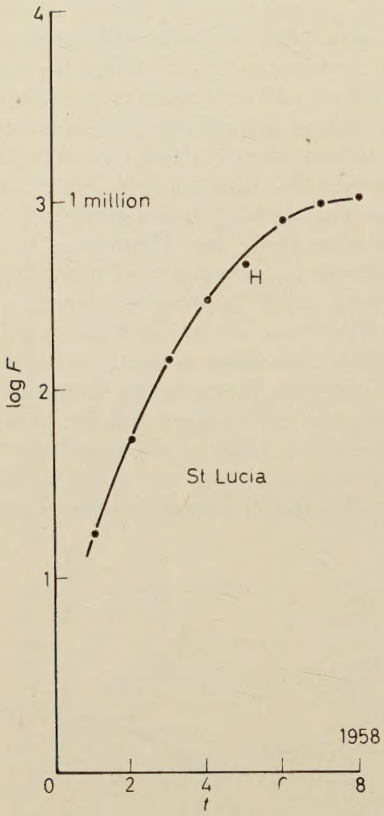

Figure 3

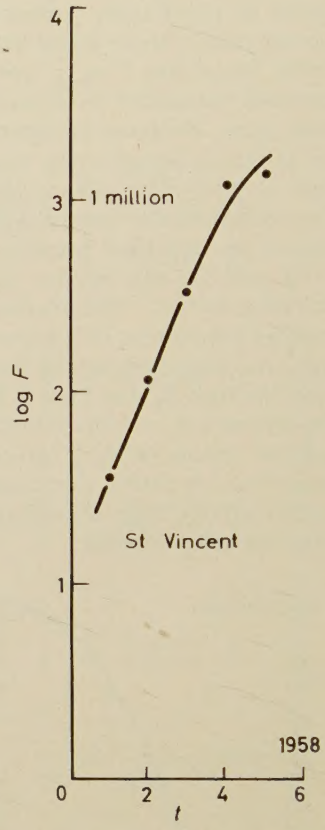

Figure 4

In column 8 an attempt is made to predict the future performance of the six trades on the basis of present trends*. For four out of the six trades, the graphs have become virtually horizontal and it therefore looks as though growth has ceased; certainly, a significant increase in production by any one of the four could happen only as a result of a radical change in the agriculture of the island—as might occur if much new land were taken into cultivation or if land now in, for example, sugar-cane were turned over to bananas. The curves for St Vincent and Grenada are still rising and extrapolation suggests that they have three or four years of growth before them. The estimated total production for 1963 and following years is about 19·3 million stems; taking into account the uncertainties of extrapolation of the graphs for St Vincent and Grenada, the limit might be as high as 22 or as low as 17 million.

*The author is well aware of the uncertainty of extrapolating empirical graphs as an aid to prediction but feels that the attempt, however perilous, is worthwhile, not least because the extrapolated figures differ materially from some of the official or semi-official estimates. It is emphasized that these predictions are made on the sole responsibility of the author and that the officials who kindly supplied the data for analysis are in no way committed to the interpretation given here.

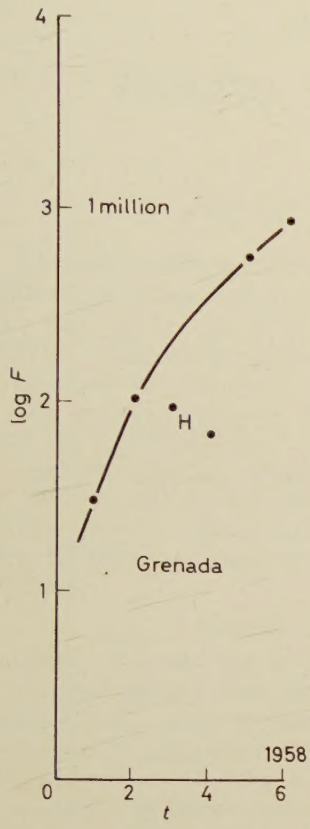

Figure 5

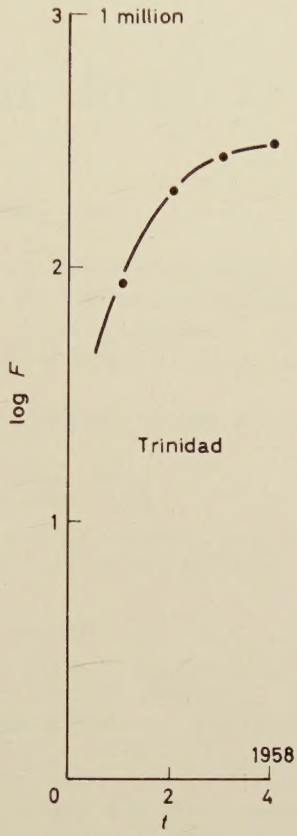

Figure 6

CONCLUSIONS

In comparison with the fivefold annual increase expected from efficient combination of fruit and sucker production, the growth rates of four out of the six trades, even in the early phases, were low and all six showed a perceptible decline in growth rate after, at most, four years. Study of the growth curves suggests that four of the trades have already reached their maxima and that the other two will reach theirs about 1963, when total production is estimated to reach about 19 million stems.

ACKNOWLEDGEMENTS

The author is much indebted to officers of the Governments of Jamaica, Dominica, St Vincent, Grenada, and Trinidad and Tobago for providing information on banana exports and for helpful comments and discussion; responsibility for the interpretation of the data, however, rests with him alone.

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Banana Growing in Israel

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The first banana orchard in the Jewish colonies of Palestine was planted in 1922 in one of the settlements of the Jordan Valley. From the beginning, only one variety was (and still is) grown, the ' Dwarf Cavendish '. This variety is supposed to have been introduced into Palestine by Arab cultivators from the Lebanon.

The banana cultivation of Israel is expanding steadily, as may be seen from the following data:

1947–48: 1 000 acres, of which 610 acres were in the Jordan Valley.
1957–58: 4 000 acres, of which only 1 400 were in the Jordan Valley.

The northern coastal area (Western Galilee and the Carmel Coast) has recently become a major centre of banana cultivation, with 1 400 acres in 1957–58.

CLIMATE AND ITS EFFECTS ON GROWTH

Israel is situated between 29 and 33 degrees north latitude and has a subtropical climate with cool, moist winters and dry, hot summers. The suitability of a place for banana growing depends on the one hand on the frequency of occurrence of temperatures lower than 18°C (65°F) during the cool season (October to April in Israel) and, more especially, on the frequency of occurrence of temperatures near or below 0°C (32°F) during the coldest months (November to March). The summer is a long season without rain and banana growing is possible only with regular irrigation during at least seven months (April to October). The mean temperature of the coldest month is 14°C (57°F) in the Jordan Valley and 13·3°C (56°F) in the Coastal Plain, but the growing season in the latter is about one month shorter. The mean temperature of the hottest month is over 30°C (86°F) in the Jordan Valley and only 25°C (79°F) in the Coastal Plain. Mean rainfall varies between 16 and 25 inches.

Many regions of the country, especially mountains and enclosed valleys, are excluded from commercial banana growing because temperatures are too low for too long a period and frosts are frequent, e.g. the mean temperature of the coldest month in Jerusalem is only 9°C (48°F).

Frosts occur even in favourable regions of the coastal plain once in three or four years and even, at longer intervals (once in eight or ten years), in the warmest part of the country, the valley of Kinroth (northern Jordan Valley). Frost causes damage to the orchards and to their fruit but neither destroys the plantations nor prevents regrowth in the following season. Even in those regions in which frost is not frequent enough to prevent banana cultivation, great importance attaches to the length of the period of interrupted growth caused by low temperatures. The shorter this period is, the more suitable is the region for banana growing.

As a consequence of the fact that, for a long period of the year, growth stops almost completely and the filling of the immature fruit is consequently delayed, the possibility of achieving high and stable yields in the banana plantations of Israel is subject to the condition that the emergence of the bunch (shooting or flowering) must be limited to a short and definite period of a few months in early summer. The success of an orchard is measured by the percentage of flowering achieved during this period. Further, not only is the size of bunch affected but the shape and quality of the fruit also depend upon the time of differentiation and emergence of the bunch. Low temperatures also lengthen the period between shooting and maturity of the bunch and this affects the distribution in time of the harvest. Since most of the crop is sold within the country, an even distribution of the harvest throughout the year would be desirable, but cannot in practice be achieved.

Differences in temperature between the various seasons cause the period between emergence and harvest to vary between 80 and 240 days, depending on the date of flowering during the period May to October. A short period of maturation (80 to 120 days) is normal only for bunches shot between May and July in the Jordan Valley and in May and June in the Coastal Plain. July bunches in the Coastal Plain need about 150 days to ripen, August bunches need about 150 days in the interior and up to 200 days at the coast and September bunches need over 200 days in both regions. Maturation is quicker in the warmer Jordan Valley than in the other regions. Beginning with the bunches shot in the month of August (especially in the second half of the month) the period of maturation lengthens considerably in all regions. Every delay of one week or ten days in flowering lengthens the period of maturity by about a month. Bunches shot in September and October remain on the plant during the winter and need 240 days or more to mature in the Coastal Plain and 210 days in the Jordan Valley.

From the climatic viewpoint the best flowering time is July and early August, the period that follows the months of optimal vegetative growth (May to July). Earlier flowering times are undesirable because differentiation during the cool season results in the appearance of small and frequently mis-shapen bunches. Thus, in the Jordan Valley, bunches shot in May bear an average of eight hands, whereas June bunches have 14, July/August bunches 19 and autumn bunches 12.

REGIONS OF CULTIVATION

There may be distinguished two main growing areas which differ climatically and therefore in the times of flowering and harvest. They are the Jordan Valley and the Coastal Plain.

The Jordan Valley

This valley has a rather warm climate and banana plantations reach a high percentage of flowering and harvest in the optimal periods mentioned above. The harvest is well distributed during eight or nine months (September to May) with a peak between November and February in the principal (second) year of harvest. Plantations in this region are relatively

secure from frost. Even more favourable winter temperatures occur near the Dead Sea [mean temperature of the coldest month at Jericho, 15°C (59°F)], but that region is less suitable for banana cultivation because of the extreme summer heat and drought; since this region is outside the boundaries of Israel (it was part of Palestine), no further details will be given about its banana orchards.

Table 1. Banana cultivation in Israel

*Month**	*Mean temperature °C*	*No. of leaves produced*	*Planting season*	*Flowering per cent*	*Bunch matures in*	*Distribution of harvest per cent*
			(*a*) Jordan Valley			
III	17·6	1·5	*Suckers*	—	—	12
IV	21·6	2·5	—	—	—	11
V	26·1	4·0	—	3	*August*	7
VI	28·5	4·5	*Corms*	7	*Sep–Oct*	1
VII	30·8	4·5	—	20	*Oct–Nov*	1
VIII	30·9	4·5	—	50	*Dec–Feb*	3
IX	28·8	4·5	—	20	*Mar–Apr*	4
X	26·2	2·5	—	—	—	7
XI	20·7	1·5	—	—	—	14
XII	16·3	0·5	—	—	—	15
I	14·0	0·0	—	—	—	14
II	14·8	1·0	—	—	—	11
			(*b*) Coastal Plain			
III	14·8	1·0	*Suckers (corms)*	—	—	17
IV	18·8	2·0	—	—	—	18
V	21·8	4·0	—	3	*August*	18
VI	23·5	4·0	—	5	*Sep–Oct*	5
VII	25·4	4·0	—	12	*Oct–Dec*	1
VIII	26·0	4·0	—	35	*Dec–Mar*	2
IX	25·0	3·5	—	35	*Mar–May*	2
X	22·6	2·0	—	10	*May–Jun*	3
XI	18·6	1·0	—	—	—	6
XII	15·0	0·5	—	—	—	6
I	13·3	0·0	—	—	—	10
II	13·6	0·5	—	—	—	12

*I—January, . . ., XII—December.

The Coastal Plain

Temperatures are lower here throughout the year than in the Jordan Valley. Consequently the dates of differentiation, flowering and harvest are much more affected by low temperatures in autumn (September to November) and in spring (March to May). The frequencies with which flowering and harvesting are achieved during the optimal season are low in comparison with those of the Jordan Valley. Differentiation during the same month in spring frequently gives a bunch of lower quality and size; the harvest is delayed and tends to be concentrated in late winter, spring and early summer, with a peak from March to May. Cases of frost damage to the fruit are more frequent.

The Coastal Plain, however, is not uniform, the northern part having more suitable climate and soil than the southern. Thus it is in western Galilee and in the strip between Mount Carmel and the sea that the greatest

concentration of orchards is to be found. Contrary to the normal rules of geography, the coastal region of Israel becomes warmer in the winter as one moves from South to North, the explanation being that the northern part lies farther away from the desert than the southern.

Figure 1. Monthly distribution of harvest in the three principal banana-growing districts of Israel. Solid line—Jordan Valley; dotted line—northern Coastal Plain; dashed line—southern Coastal Plain. Months: I—January . . . XII—December

SOILS

The Jordan Valley

Banana plantations are found mainly in the wide plain that lies south of the Sea of Galilee and east of the river Jordan but inside Israel's territory. The soil of this plain is of alluvial origin, with a high pH and high lime content (about 40 per cent). The upper layers of these soils are well drained, but difficulties in draining the lower layers have developed after many years of irrigated agriculture. This has necessitated the construction of a subsoil drainage system at a depth of two metres.

In this soil, banana orchards are not long-lived, being normally kept for two or three harvests only. After this the plants are uprooted and new orchards established. The banana in this region is a component of a rotation of irrigated crops; in a period of nine or ten years, the land is kept under bananas for four years (three crops), two or three years are used for dry cultivation and preparation of the land, and for two or three years

other irrigated crops (alfalfa, tomato, potato, fodder plants) are grown. Thus bananas may be replanted on the same land after a break of six or seven years. The soil is prepared by very deep ploughing.

The Coastal Plain

The soils here are of two kinds; (*a*) alluvial soils and (*b*) brown-red sandy loams. The alluvial soils are brown or grey in colour; their clay content varies between 30 and 65 per cent, and they contain between 2 and 30 per cent of lime. To the extent that their physical qualities are suitable and their drainage satisfactory, bananas grow very well in these soils. Plantations can usually be kept for four to six harvests but, under the best conditions, may live much longer. The best orchards, giving good returns for ten to fifteen years, are found on soils with a high content of organic matter and excellent drainage that results from the presence of a predominantly rocky subsoil. Such soils are found in large uniform areas only in two regions, one in western Galilee and the other between Mt Carmel and the sea. However, flourishing banana orchards can be found even on relatively shallow soils with a depth of not more than 30 to 40 cm, overlying gravel or rock.

The brown-red sandy loams are derived from sandy limestone. The heavier of these soils (favoured for banana cultivation) have a clay content of 12 to 35 per cent; they contain a certain amount of lime and are deep and fairly uniform. Like the alluvia, these loams also occur in patches in small areas between poor sandy soils of low fertility where bananas should not be planted. Few plantations reach old age and most are kept for only four or five harvests. Yields are usually lower than those obtained on the fertile alluvial soils.

MANAGEMENT

Planting material

Until quite recently the common practice in Israel was to plant new banana fields with suckers which bore a maximum of 22 to 24 leaves but had not differentiated the bunch. Younger suckers, with fewer than 18 leaves, should not be used because, under the normal climate of Israel, they are too immature to flower during the summer and early autumn, the optimal period described above.

Corms are commonly used for planting in tropical countries and, in the course of the years, many growers have tried to use them in Israel, especially in the Jordan Valley. Despite the advantages of this type of material (high yield, flowering and harvesting in the optimal period) corms have not yet been generally used though it seems likely that this type of material will become more common in the near future. In 1958, corms were planted on 15 per cent of the newly planted area in the Jordan Valley, 20 per cent of the northern coast area and 4 per cent of the central and southern coast area.

Planting time and growth of first crop

Planting is done mainly in March. Flowering occurs five to seven months later, i.e. between August and October. The main harvest time for the

first crop is between March and June of the following year. This first crop, because it comes from plants that flower late in the year, fills out in the winter months and thus takes between 180 and 240 days to mature. The interval between planting and harvesting the first crop is therefore about 12 to 15 months.

In fields planted with suckers (as distinct from those planted with corms) the loss of leaves sustained by the suckers during transplantation causes the first crop to be smaller than subsequent crops. This is seen mainly in the smaller bunch (seven to nine hands in the first crop as against 10, 12 or more in the second and third crops) and, in certain conditions, also in smaller fingers.

The relatively disadvantageous effect of planting suckers (as against corms) is felt more strongly in the Jordan Valley, with its rapid development consequent on more favourable temperatures, than in the coastal plain. The first crop from suckers tends to mature in the spring months when the market is likely to be over-supplied with fruit from the coastal plain.

Timing the second and later crops

Within certain limits, the experienced grower is able to influence the time of flowering (and thus the time of harvest) by the proper selection of followers and by the regulation of the number of suckers left in each stool. In the Jordan Valley this possibility is practically limited to the second crop. Owing to the general delay in the appearance of followers for the third crop and their slow development, the scope of selection narrows considerably. This makes choice of suckers of the proper size impossible in many stools and a steep decrease both in size and quality of bunches is experienced between the second and third crops. The reason for this downward trend is not fully established; it may be that changes in the physical condition of the soil are responsible but nematode infestation may also be involved. The growers of the Jordan Valley try therefore to obtain the highest possible second crop by leaving two suckers in each stool and then destroy the plantation after the third crop.

In the Coastal Plain the situation is different. The adverse effect on the first crop of using suckers for planting is much less severe than in the Jordan Valley and acceptable bunches (nine or ten hands), and thus a fair harvest, can be obtained in the first year. Furthermore, in suitable soils the lowering of the yield after the second crop is not as rapid as in the Jordan Valley and, usually, the third crop is as good as the second. Indeed, many plantations preserve a high yield and produce good quality fruit even in later years. Due to the longer season of sub-optimal temperatures, the dates of flowering and harvest are generally later than in the Jordan Valley; consequently, the period of maturation of the fruit is lengthened and the bulk of the harvest is concentrated (even in the second and third year of the orchard) between February or March and May.

Yields in relation to age of plantation

The following data for yields are considered satisfactory. They include some fruit of inferior quality, used only locally.

Crop-year	*Yield (tons per acre)*	
	Jordan Valley	*Coastal Plain*
1st	4	6
2nd	12	8–10
3rd	6	8–10
4th	destroyed	5 (or more)
5th and later	—	5

Planting distances and plant population

Bananas are generally planted at 3 × 3 to 2·5 × 2·5 metres, equivalent to 440 to 600 stools per acre; populations in excess of 500 stools per acre are the commonest.

As mentioned above, the common practice in the Jordan Valley is to leave two followers per stool in the second crop and, as far as possible, also in the third; a mean value of 1·5 may be obtained by alternate thinning to two and one follower. Plant populations after the first crop are, therefore, about 1 000 per acre.

In the Coastal Plain the most common method is to thin to one follower per stool for all ages of the orchard. The aim is to accelerate development and thus achieve the earliest possible flowering time. But, quite frequently, this one sucker would be too vigorous and would flower too early, resulting in a worthless bunch differentiated during the cold season; in such cases, two suckers must be left.

Irrigation

All banana orchards in Israel are irrigated, usually for a period of about 200 days, between April and October. In the Jordan Valley most orchards are irrigated by flooding every ten to fourteen days (16 to 20 irrigations per season) at the rate of 100 to 120 acre-inches*. In the Coastal Plain, water is applied mostly by sprinkler at somewhat shorter intervals (20 to 25 irrigations per season) but with much smaller quantities of water—40 to 50 acre-inches*.

Manures and fertilizers

Animal manure is applied every year at the rate of 12 to 24 tons per acre. Sulphate of ammonia is given twice yearly at the rate of about 200 kg (about 4 cwt) per acre. Potash is given (if at all) only in the Coastal Plain, at the rate of 200 kg (about 4 cwt) of muriate of potash per acre.

Pests and diseases

So far, pests and diseases have not been recognized as a limiting factor in the cultivation of the banana in Israel. Panama Disease, Cercospora leaf spot and Bunchy top virus are absent. Fruit rots occur in some orchards of the Coastal Plain, but their importance is not very great.

Burrowing nematodes of a number of species are present and the problem of their importance is under investigation. As mentioned above, their rapid increase in the second year of the orchard in the Jordan Valley may have some bearing on the deterioration of the orchard after the second harvest.

* Quantities of irrigation water are reckoned as cubic metres per dunum in Israel. The dunum is a quarter of an acre and one inch per acre is equivalent to 26 cubic metres per dunum (approximately).

PRODUCTION AND MARKETING

In the year 1947–48, when the State of Israel was established, banana plantations extended to 1 000 acres. Now, in 1958, the area has grown to 4 000 acres, of which about one third is in the Jordan Valley. The annual expansion has been nearly 400 acres, but a slowing down of this pace is to be expected in the years to come. The future rate of increase is difficult to forecast because it depends on the rate of population increase which depends to a very high degree on the rate of immigration. It is tentatively estimated that in another ten years there may be about 7 000 acres of banana orchards in Israel.

Nearly 90 per cent of all the banana orchards are to be found in workers' settlements (most of them collective) which cooperate in running their own Fruit Growers' Organization; the produce is marketed through the Fruit Growers' Marketing Organization, called *Tnuva*.

The total crop of bananas (including all sizes and qualities) was about 25 000 tons in the 1957–58 season. Out of this total some 1 500 tons was exported, mainly to Greece and Jugoslavia. Many difficult problems are involved in this trade and its prospects are not at all clear. Apart from this small export trade, the crop is consumed locally and the main market is in the larger towns of the country. For this reason, it is desirable that the harvest should be distributed as uniformly as possible in time. The closeness with which this ideal is approached depends on the relative share of the various regions (cf. *Figure 1*), on details of management and on the age distribution within the orchard.

The resultant seasonal distribution has, in recent years, been as follows:

Period	*Per cent of total crop*
June–September (4 months)	12 per cent (small supply)
October–February (5 months)	45 per cent (good supply)
March–May (3 months)	43 per cent (abundant supply with tendency to over-supply)

Prices fluctuate in relation to supply—so that the grower must, when choosing followers, take into account not only the probable size of the bunch but also the probable time of harvest in relation to price. Taking the price in January/February as 100 per cent, prices fall to a minimum of 75 per cent in April and May and then rise to a maximum of about 130 per cent in September and October. Prices are influenced by climatic factors which in turn influence both size and distribution of the harvest. In addition, prices are influenced by external factors, i.e. the size of the harvest of other fruits. Prices for exceptionally high and low quality fruit may be up to 20 per cent higher or lower than the norm.

Per capita consumption in Israel in 1957–58 was about 13 kg, roughly equivalent to two to three bananas per week. By temperate zone standards this is an exceptionally high consumption, which markedly exceeds that found in North America and is approximately twice as high as consumption in Western Europe.

Fruit is harvested green and sent by truck to the markets in the large towns. Commercial ripening is carried out by the Marketing Organization, in heated or cooled rooms, according to market conditions. The most suitable temperature for normal ripening is 16° to 18°C (61° to 64°F)

with the addition of 1 : 1 000 parts ethylene to the air of the ripening chamber. During the last few years, packing houses have been built in the important growing areas; there the fruit is cut into hands, packed in crates in the green condition and ripened in the crates before dispatch to the town markets. In the last season (1957–58) about 10 per cent of the total harvest was marketed in this way.

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The Effect of Deficiencies of the Major Nutrients on Growth and Leaf Analysis of the Banana

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Murray (1959) has described the production of visual symptoms of deficiencies of nitrogen, phosphorus, potassium, calcium and magnesium in the banana. In the course of this work, the opportunity was taken of making various growth measurements on the plants and of sampling material for leaf analysis. The sand culture technique used has already been described and details will not be repeated. The variety used was the Dwarf Cavendish. As the plants were grown in a glasshouse there was little trouble with leaf spot and no spraying was necessary.

GROWTH MEASUREMENTS

The habit of growth of the banana with its serial production of leaves lends itself to straightforward methods of assessing growth. Each new leaf as it emerged from the sheathing leaf base of the previous leaf was labelled with the date of emergence and when it had unfurled its length and bre adth were measured. The shape of a banana leaf is reasonably constant whatever its size and a fair approximation of leaf area is given by multiplying the product of length and breadth by the factor 0·8.

Two plants were grown for each deficiency and *Figure 1* shows the effect on rate of leaf production and total leaf area for the plants of one series. Although representation should be more properly stepwise as each leaf unfolds the method employed is more convenient. The horizontal distance between points indicates the interval in days between the emergence of the leaves and the corresponding vertical distance the area of the new leaf.

Since the experiment was not primarily planned to investigate growth relations, numerical assessment of the relative effects of the various deficiencies cannot be made. Certain features do, however, stand out, more especially the early and marked effect of withholding nitrogen. Obviously the situation is complicated by the original weight of the sucker and its reserve of nutrients but it seems reasonable to say that the plant may produce its first half dozen leaves with reserves from the corm of all nutrients except nitrogen. An immediate external source of this nutrient is required if growth is not to be severely retarded.

After some four months growth, absence of phosphorus, potassium and calcium gives plants with leaf areas only a little more than half that of the control. The absence of magnesium has a less pronounced effect at this stage though leaf symptoms of deficiency were by then apparent.

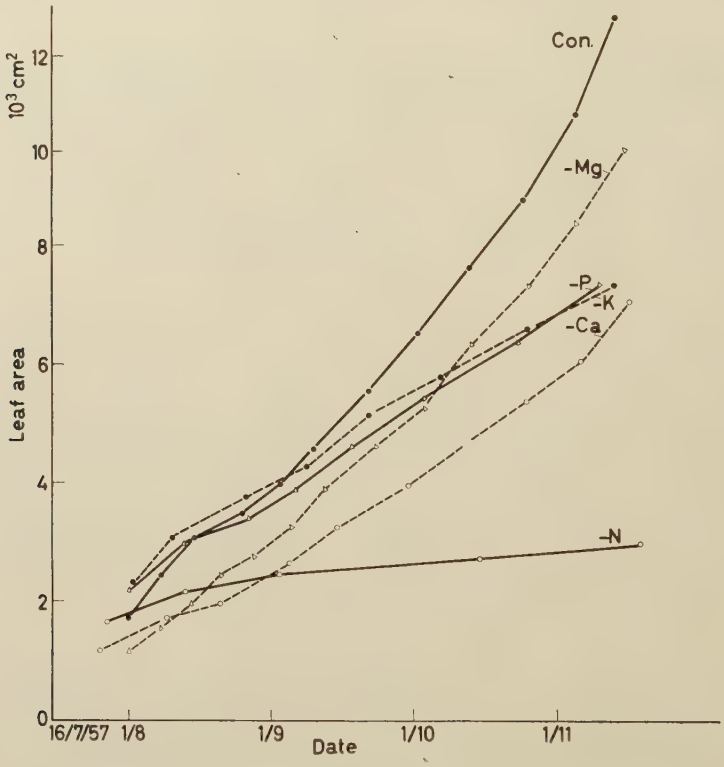

Figure 1. Increase in leaf area in cm², for plants grown in absence of the various major nutrients

The total number of leaves produced and the interval between their appearance is given in *Table 1* for the period 16/7/57 to 21/12/57, the first 158 days of growth.

Table 1. Number of leaves produced in 158 days and average interval between leaves

Element	*No. of leaves*	*Days between leaves*
Control	16·5	9·5
—N	7·0	22·6
—P	13·0	12·1
—K	11·5	13·8
—Ca	13·5	11·7
—Mg	14·5	10·9

Under good growing conditions in the field a leaf may be expected every seven days so that growth of the control appears slightly sub-optimal. The fact that appreciable growth has been made for five months in the complete absence of any external source of the various nutrients except nitrogen is an indication of the importance of the nutrient reserves in the corm.

Measurements of pseudostem girth showed a similar retardation in growth with the various deficiencies but are not of sufficient importance to be recorded here.

Weight increase

Once the deficiency symptoms had developed and been described the plants were removed from their pots. After washing the sand away each plant was divided into roots, corm, pseudostem and leaves. Each was weighed and samples were oven-dried.

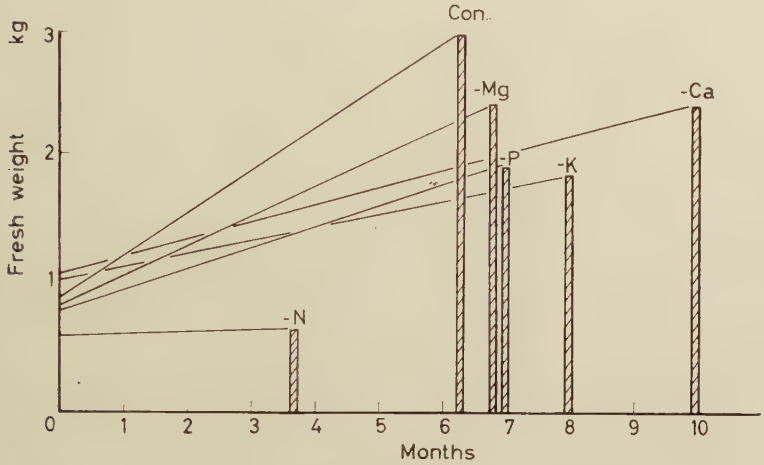

Figure 2. Final weight of plants grown in absence of the various major nutrients

Since the time of harvesting varied with the appearance of the deficiency symptoms, no direct comparison of the plants is possible. *Figure 2*, however, shows the final wet weight of the plant in relation to its harvesting date. Rate of growth should obviously be curvilinear but the slope of the straight line joining the final weight of the plant to the original weight of the corm gives some measure of the average growth rate. From these slopes has been calculated the rate of growth as a percentage of the control plant. Compared with 100 per cent growth for the control, deficiency of nitrogen, phosphorus, potash, calcium and magnesium results in rates of weight increase of only 3, 53, 35, 44 and 74 per cent respectively over the period.

The distribution of weight between the various parts of the plants is given in *Table 2*. Since they were sampled at different times the data are not directly comparable. They do, however, indicate certain relationships that are altered by the deficiencies. Omitting the weight of the corm, the shoot/root ratio for the control plant is 3·6; with nitrogen and

Table 2. Fresh weight in grammes of the various parts of the plants at harvesting

Element	*Roots*	*Corm*	*Pseudostem*	*Leaves*	*Total*
Control	466	713	1 292	593	3 064
—N	116	612	101	30	859
—P	523	682	600	183	1 988
—K	406	705	1 330	372	2 813
—Ca	135	1 060	925	343	2 463
—Mg	602	367	1 386	508	2 863

phosphorus deficiencies the ratio falls to 1·1 and 1·5 respectively; potassium and magnesium deficiencies have little effect on it, and with calcium deficiency it rises to over 9. Lack of calcium has a very pronounced effect on root development.

Water loss

Since the culture solutions were always made up to two litres daily the amount of demineralized water required to do this gives a measure of the daily transpirational loss from the plant. The tops of the pots were covered with polythene sheeting so that loss from the sand surface would be inappreciable.

The method cannot be expected to yield precise information over short periods, since complicating factors such as the amount of water retained by the sand may vary at each watering. Details are presented in *Table 3*, however, of the comparative water loss over four-day periods in two consecutive weeks. The data comprise the sum over four days of the additions of water made at 9 a.m. and 2 p.m. daily to restore the two-litre level. The leaf area is functional leaf area and omits all dead leaves. The measurements were taken in the height of the dry season, when the plants were eight months old and the deficiencies were very pronounced. By then the nitrogen-deficient plants had already been sampled and no data are available for them.

Table 3. Daily water loss per plant and per dm² leaf area for two 4-day periods

Element	*Leaf area, dm²*	*Water loss in cm³/day*			
		Per plant		*Per dm² leaf area*	
Control	26·8	1 897	1 725	7·0	6·4
—P	22·8	1 177	1 085	5·1	4·8
—K	14·6	669	640	4·7	4·5
—Ca	18·6	830	832	4·4	4·4
—Mg	7·8	350	237	4·4	3·1

It is obvious that the plant with the largest leaf area, i.e. the control, has the highest daily water loss. On some days over two litres of water was required to replace that lost. Where water loss is calculated per square decimetre of leaf area, however, it would appear that all the plants with induced deficiencies are losing less water per unit area of leaf than the control. Clearly, however, far more precise experimental methods would be needed to investigate the significance of this.

LEAF ANALYSIS

Leaf analysis can provide a powerful technique for the detection and correction of unbalanced nutrition in the plant. Its success as a technique varies, however, from crop to crop and in general this is due in no small measure to the difficulties involved in taking samples. Since the nutrient balance in the leaf is determined not only by the availability of nutrients but also by the age of the leaf and even, in a crop such as cacao, by the light intensity at which the leaf is growing, it is important that samples

should be such as to minimize the effect of factors other than the availability of soil nutrients.

The sampling problem is easier in the monocotyledons where there is a serial progression of leaves at fairly regular intervals. Samples can therefore be taken from leaves which bear a constant relation to the youngest leaf and are thus of comparable age. This is undoubtedly one reason why leaf analysis has proved so successful in sugar-cane, and in both the oil palm and the coconut palm leaf analysis has been carried out using samples from a leaf of known age.

It follows that the banana should also be amenable to a fairly precise system of leaf analysis. HEWITT (1955), working in Jamaica, has investigated the possibilities of leaf analysis in the field. He first determined the contents of nitrogen, phosphorus pentoxide and potassium oxide in the first, third, fifth and seventh leaves of the plant and decided to adopt the third leaf as the standard for sampling. Then from field fertilizer trials he established tentative values below which yield was diminished. These levels were: N—2·6, P_2O_5—0·45 and K_2O—3·30 per cent. No analyses were carried out for calcium or magnesium.

The production of plants showing deficiency symptoms of the major elements now provides material whose analysis can give the levels of the various nutrients at which the deficiency symptoms are apparent.

When the plants were harvested they were divided up into roots, corm, lower pseudostem—i.e. just above the corm, upper pseudostem—i.e. near the apex, and each leaf was sampled separately. After oven-drying, the material was ground and stored for analysis.

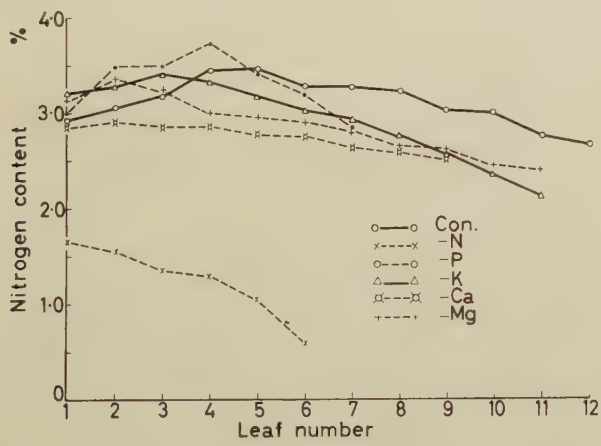

Figure 3. Nitrogen content versus age of leaf

Figures 3 to *7* show the levels of nitrogen, phosphorus, potassium, calcium and magnesium for successive leaves of the plants with the various deficiencies and the control plant. The number of leaves varies since with certain deficiencies the older leaves are lost prematurely.

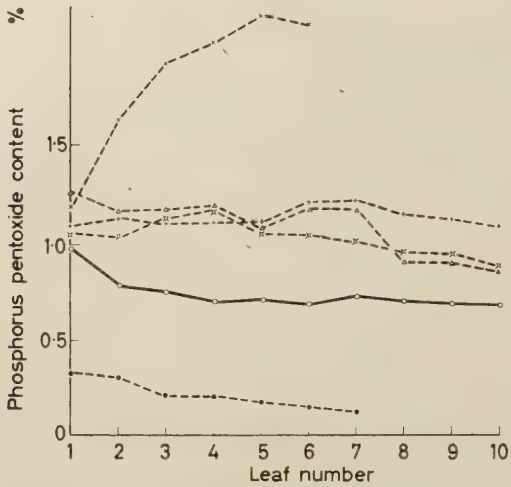

Figure 4. Phosphorus content versus age of leaf

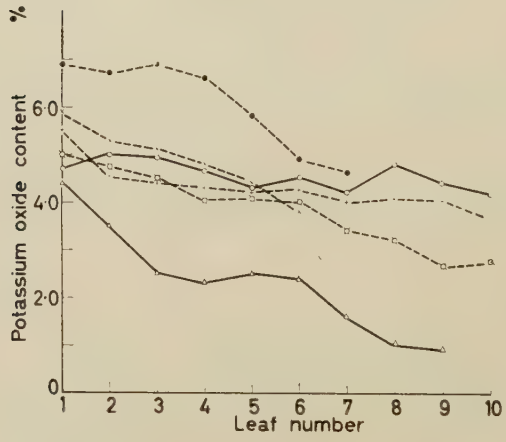

Figure 5. Potassium content versus age of leaf

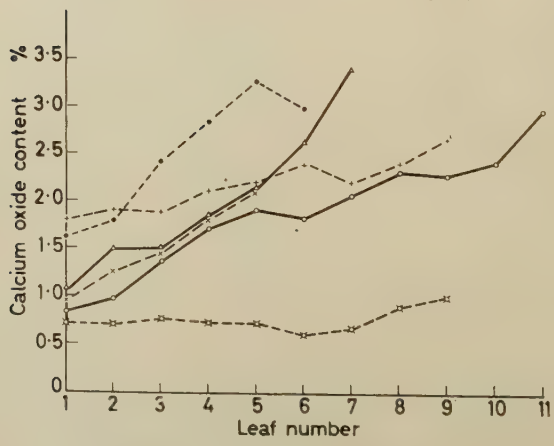

Figure 6. Calcium content versus age of leaf

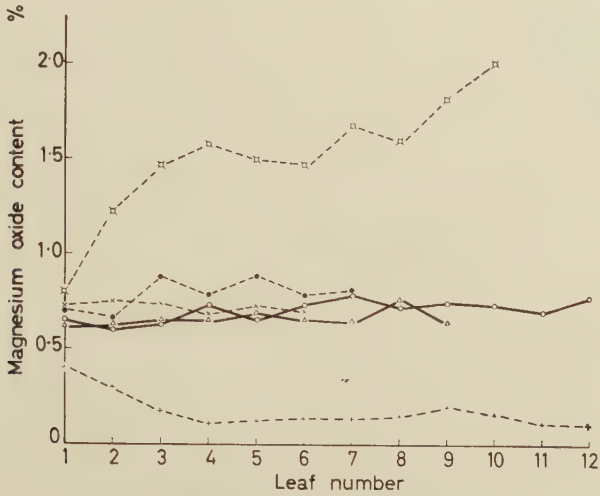

Figure 7. Magnesium content versus age of leaf

Nitrogen content

The distribution of nitrogen in the leaves of the control plant shows a slight rise from the youngest leaf to the fourth and then a progressive fall with increasing age of leaf. Hewitt's data follow a similar pattern. The low levels found in the nitrogen-deficient plant are obvious, but the highest level is found in the youngest leaf with a progressive falling off with age. Hewitt found a range in the field from 3·8 down to 2·3 per cent and gives 2·6 per cent as the level below which yield is reduced. A level as low as 1·35 per cent nitrogen in the third leaf would seldom occur in the field but indicates the wide range between adequacy and acute deficiency. The effects of the other deficiencies on leaf nitrogen follow in general the pattern for the control plant. Calcium deficiency seems to depress nitrogen levels and so do deficiencies of the other cations more especially in the older leaves. With phosphorus deficiency some accumulation of nitrogen occurs in the young leaves.

Phosphorus content

The percentage of phosphorus pentoxide in all the leaves of the control plant after the first is remarkably constant. With deficiency, the levels fall to about one third of those found in the corresponding healthy leaf and a slight gradient occurs. Deficiencies of the other nutrients lead to phosphate accumulation and this is particularly marked for nitrogen deficiency. Hewitt's range in the field of 0·81 to 0·53 per cent phosphorus pentoxide is very narrow compared with the range shown here, and the levels in the control plant tend to be high by field standards.

Potassium content

Again, in regard to potassium, the leaves of the control plant show very little fall in potassium content with increasing age. This is in contrast to the potassium-deficient plant where not only is there the expected low level but the gradient with increasing age of leaf is very pronounced. A

somewhat surprising feature is that deficiencies of calcium and magnesium lead to no accumulation of potash, the values being very similar to those of the control plant. In most plantsantagonism between the cations leads to considerable accumulation of those in adequate supply when one is deficient. Increased levels of percentage potassium oxide result, however, from a deficiency of phosphorus. Hewitt found a range in the field in Jamaica from 2·68 to 5·17 per cent in the third leaf and considers a level of 3·30 per cent to be adequate for optimal growth.

Calcium content

In the control plant there is a steady rise in calcium content with age of leaf, the normally expected feature. In the calcium-deficient plant the level in the youngest leaf is not greatly below that of the control but there is no accumulation of calcium with age, the oldest leaves having much the same percentage content as the youngest. This is rather unexpected and would seem to indicate a greater mobility of calcium in the banana than in most other plants for which data are available. With potassium deficiency there is the expected accumulation of calcium, more especially in the older leaves. Accumulation with magnesium deficiency is far less pronounced. Absence of phosphorus also results in marked increase in calcium.

Magnesium content

Finally the effect of the treatments on magnesium content is shown in *Figure 7*. In the banana the small range in percentage magnesium oxide between the young and old leaves of the control plant is unusual as magnesium like calcium tends to accumulate with age in most plants. The low levels associated with magnesium deficiency are obvious. The high levels associated with calcium deficiency are to be expected but again it appears rather anomalous that potassium deficiency does not result in some degree of accumulation of magnesium also.

Summarizing now the overall effect on the nutrient balance of the leaf of a deficiency of any one of the major elements:

Nitrogen deficiency, besides the expected low level of nitrogen, results in an increase in the phosphorus content but little change in the levels of the cations except magnesium where there is some depression. With phosphorus deficiency there is some accumulation of nitrogen, and a considerable increase in potassium and calcium but not magnesium. Potassium deficiency tends to increase phosphorus content and also calcium but there is little effect on magnesium. With a deficiency of calcium, the level of phosphorus is raised and also that of magnesium. There is no appreciable effect on potassium content. Magnesium deficiency results in very little change in the levels of the other nutrients apart from an increase in the phosphorus content.

These changes in balance may prove as valuable a method of diagnosis as the measure of the actual level of the suspected deficient nutrients. An examination of nutrient ratios is not, however, considered justified now in view of the small number of plants that have been available for analysis.

The analyses of the roots, corm and pseudostem are given in *Table 4*. Certain values appear anomalous but no general discussion is undertaken in view of the small number of plants involved. The partition of nutrients in the plant in relation to deficiencies would entail a far more detailed experiment.

Table 4. Percentage nutrient content of roots, corm and pseudostems with deficiencies of the major nutrients

Element		%N	$\%P_2O_5$	$\%K_2O$	%CaO	%MgO
			Roots			
Control		2·37	1·33	6·30	1·70	0·99
—N		**1·01**	0·51	4·55	1·45	0·72
—P		2·09	**0·21**	4·60	1·80	0·67
—K		1·82	0·97	**2·70**	2·65	0·73
—Ca		1·94	0·84	6·10	**1·10**	0·69
—Mg		1·74	1·06	5·20	2·70	**0·40**
			Corm			
Control		2·65	1·71	4·30	0·90	0·52
—N		**0·24**	0·92	4·00	1·00	0·58
—P		1·47	**0·14**	4·15	1·40	0·57
—K		0·73	1·04	**2·95**	1·60	0·93
—Ca		1·16	1·50	6·40	**1·29**	0·74
—Mg		1·55	1·47	7·10	2·50	**0·45**
			Pseudostem			
Control	*Base*	1·23	0·98	8·70	3·20	0·56
	Top	2·28	1·57	7·20	3·35	0·52
—N	*Base*	**0·56**	2·24	5·30	1·40	0·45
	Top					
—P	*Base*	3·03	**0·15**	6·45	3·65	1·35
	Top	3·02	**0·18**	10·05	3·55	0·64
—K	*Base*	2·77	2·50	**3·15**	4·55	1·51
	Top	2·21	2·05	**2·00**	3·35	1·36
—Ca	*Base*	2·70	1·89	12·80	**1·80**	0·30
	Top	2·70	1·96	9·75	**3·24**	0·55
—Mg	*Base*	4·29	1·62	8·40	3·65	**0·16**
	Top	3·43	1·36	9·50	4·10	**0·15**

DISCUSSION

The results of the effect on growth of the banana of deficiencies of the major nutrients are straightforward. Appreciable growth is possible from the store of nutrients in the corm except in the case of nitrogen. Absence of an external source of this nutrient is shown very soon in the stunted growth of the young sucker.

As regards leaf analysis the habit of growth of the banana provides a great advantage over dicotyledonous crops where the age of leaf at the time of sampling is difficult to ascertain. By the use of material bearing a fixed relationship to the youngest spear leaf comparisons between plants will not be invalidated by age drifts in the leaf. Hewitt's choice of the third leaf would appear quite satisfactory.

For those nutrients that tend to accumulate with age of leaf, more especially calcium, analysis of an older leaf would give a better indication of deficiency. Against this, however, would be the disadvantage of having double the number of samples. The use of gradients between young and old leaves as a measure of nutrient strain does not seem to have received

much attention in the literature of leaf analysis. Early senescence as a result of deficiency is of course a marked feature of nutrient unbalance and with deficiency, more particularly of the more mobile nutrients, these tend to move from the old tissues to the young.

The level of a nutrient at which visual deficiency symptoms occur has been shown for the major nutrients to be considerably below the level at which optimum growth is made. Clearly cropping will be reduced long before visual symptoms are apparent. The following provisional table has been drawn up.

Table 5. Percentage nutrients in third leaf

	N	P_2O_5	K_2O	CaO	MgO
*Adequacy**	2·6	0·45	3·30	1·40	0·60
Severe deficiency	<1·5	<0·20	<2·50	<0·75	<0·20

* N, P_2O_5 and K_2O data from Hewitt; CaO, MgO from controls.

Obviously more information is required for the region between adequacy and severe deficiency. This could be secured by more detailed studies in sand culture with varying concentrations of the particular nutrient in the culture solution. The leaf nutrient levels could then be correlated with growth measurement. Further field studies similar to those of Hewitt would also have to be undertaken.

There do not appear to be any reasons why a technique for leaf analysis for the banana could not be developed and prove as valuable to the banana industry as it has proved to the sugar-cane industry. In many places fertilizers are applied with little knowledge of the true requirements of the crop on the particular soil. Substantial economies could undoubtedly be effected if a fertilizer programme was based on leaf analysis. It would then be possible to apply fertilizers only as required by the plant for optimum cropping.

No consideration has been given to the fact that the plants were grown in a glasshouse at a light intensity of only some 60 to 70 per cent of full sunlight. It is not unlikely that this factor, as with cacao, may affect nutrient levels so that caution would be necessary in relating these results to field conditions. Further experimental work is in hand to investigate this point.

SUMMARY

The reduction in rate of growth of the banana as measured by rate of leaf production has been shown for the various major nutrients. Supplies of nutrients in the corm will permit growth for some considerable time except in the case of lack of nitrogen.

The leaf levels of nitrogen, phosphorus, potassium, calcium and magnesium as they are affected by deficiency have been determined. The levels at which visual symptoms occur are considerably below those at which growth is reduced.

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The Control of Parasitic Eelworms in Bananas

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The presence of parasitic eelworms in and on banana roots has been known for many years but, in general, the Gros Michel variety shows a considerable degree of tolerance. During the past 20 years, however, the importance of this variety has declined in favour of members of the Cavendish Group and these, in particular the Lacatan, may be severely damaged by eelworms. Recently Leach (1958) drew attention to the symptoms of blackhead and toppling in Lacatan, which are due to severe eelworm damage by *Radopholus similis.*

In the Southern Cameroons, the Gros Michel is still the main export variety, but for the past five years the Cameroons Development Corporation has been actively seeking an alternative variety because practically all the first class banana lands are riddled with Panama Disease (*Fusarium oxysporum* var. *cubense* E.F. Smith). Attention has been focused primarily upon Lacatan, Giant Cavendish and Robusta pending the production of a good tetraploid banana by the Banana Breeding Scheme.

Although the coastal climate of the Southern Cameroons is, in the main, suitable for banana cultivation the beginning and end of the rainy season are heralded by ' blowdowns ', which are minor tornadoes that rarely attain great intensity but always wreak havoc on the banana plantations. The cultivation of varieties susceptible to eelworm damage will undoubtedly increase the risk of ' blowdown ' losses.

The problem of controlling eelworm is, therefore, one that must be solved if a Cavendish Group variety is to be grown profitably, and in April 1959 an experiment to test the effect of applications of Nemagon* on the growth and yield of Lacatan was commenced. The preliminary results of the effect on vegetative growth, it was thought, were of sufficient interest to publish now rather than in conjunction with the effect on the fruit which will be published later.

Although it is recommended that Nemagon should either be injected into the soil or a granular formation forked into the topsoil, neither of these methods could be carried out economically on a plantation scale. Injection would be very expensive in labour and the necessity to maintain a mat of cover crop for soil conservation precludes the forking in of granules.

Excavation of the root system of Lacatan bananas showed that 70 per cent of the roots lay within the top six inches of the soil and it was thought that watering on Nemagon just before the heavy rains might give a good measure of control. A factorial experiment consisting of a control treatment with no Nemagon, Nemagon injected at a rate of three gallons

*Shell Trade Mark for a 1,2-dibromo-3-chloropropane formulation.

per acre and an overall watering of Nemagon of three gallons per acre was planted in April 1959.

The injected treatment consisted of injecting each mat at four equally spaced sites one foot from the plant, and eight sites two feet from the plant.

The Nemagon 75 EC was diluted so that 15 ml of liquid was delivered at each injection. This was carried out one week after planting.

The watered-on treatment consisted of slashing back the ground cover and watering-on at a rate of four gallons of dilute fluid in the area between the mats, which were planted ten feet apart on the square. The experience gained in this latter treatment suggested that much less liquid could have been applied successfully.

RESULTS

After only five months from planting treatment differences became obvious notwithstanding that the ' seed ' was very small. In December, nine months after planting, measurements of the circumference six inches above ground level on 25 mats were made at random in each plot. The mean values multiplied by ten are given in *Table 1.*

Table 1. Mean circumference at six inches above ground level, times ten

Treatment	*Replication* 1	2	3	4	*Total*
Control	387	398	320	293	1 398
Nemagon injected	420	484	391	364	1 659*
Nemagon watered	446	496	370	474	1 786**
Total	1 253	1 378	1 081	1 131	4 843

The significant difference, calculated on the pooled residual error at the 0·1 per cent level is 337 and at the 0·5 per cent level 222. The mean treatment results are given in *Table 2* below.

Table 2. Mean treatment results

Treatment	*Circumference*	*% increase over control*
No Nemagon	34·95	100
Nemagon injected	41·48*	119
Nemagon watered	44·65**	128

It is clear that the application of Nemagon has resulted in stronger, sturdier growth and it would seem that when watered the effect is greater than when injected.

The number of leaves per plant was also counted at the same time as the circumference measurements were taken. The mean values for number of leaves multiplied by ten are given in *Table 3.*

Table 3. Mean number of leaves per mat per sample, times ten

Treatment	*Replication* 1	2	3	4	*Total*
Control	120	115	102	107	444
Nemagon injected	126	123	116	113	478*
Nemagon watered	122	120	108	120	470*
Total	368	358	326	340	1 392

The significance difference calculated on the pooled residual error at the 0·5 per cent level is 25. The mean treatment results are given in *Table 4.*

Table 4. Mean treatment results

Treatment	*Mean number of leaves*	*% increase over control*
No Nemagon	11·1	100
Nemagon injected	11·9*	107
Nemagon watered	11·7*	105

As with the results for circumference it is clear that the application of Nemagon has resulted either in improved leaf production and/or leaf retention.

Both sets of results confirm the recently published work by VILARDEBO (1959).

DISCUSSION AND CONCLUSIONS

It is evident that, at last, there is a means available to control the depredations of eelworm in bananas and a preliminary appraisal of the cost of chemical and cost of application in the Southern Cameroons suggests that to be profitable the crop must be increased by about ten per cent. Regression lines of fruit weight on circumference drawn for Gros Michel suggest that an increase in circumference of 28 per cent results in an increased fruit weight of 56 per cent (HASSELO, 1955). If this ratio is valid for members of the Cavendish group then the application of Nemagon should be profitable and as a result consideration is being given to three ways of applying Nemagon on a plantation basis:

(*1*) Large scale injections, which may prove expensive and would be difficult to supervise

(*2*) Watering-on a dilute fluid with a tractor and spray boom, which would be difficult in the Southern Cameroons because of water shortages

(*3*) Compounding Nemagon into the balanced fertilizer that is applied in May before the heavy rains.

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Observations on the Diseases of Cacao Pods in Papua–New Guinea—I

Fungi Associated with Mature Pods

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In English-speaking countries the term 'black pod' is used to describe the disease of cacao pods with which *Phytophthora palmivora* is associated. This usage has been criticized by Briton-Jones (1934) because it describes a symptom which is common to a number of diseases of, or injuries to, cacao pods. As commonly used in Papua–New Guinea, the term refers to any blackened pod irrespective of the cause of discoloration.

The observations reported in this paper were made at the Lowlands Agricultural Experiment Station at Keravat, some 30 miles from Rabaul in the Gazelle Peninsula of New Britain. In this district, the soil has been derived from recent deposits of volcanic pumice and the original vegetation was rain forest with patches of open grassland. During the period 1950–56 inclusive the mean annual rainfall was 105·75 inches; the wet season coincides with the northwest monsoon which nominally lasts from November until April.

Several investigators (e.g. Dade, 1927; Thorold, 1955) have stressed the importance of rainfall and relative humidity to the development of black pod. During 1955 the months July to December were unusually dry in the Gazelle Peninsula but, despite conditions that were unfavourable to the development of *P. palmivora*, 'black' pods continued to appear. Accordingly, attention was given to this aspect of the disease.

The practices associated with cacao cultivation in Papua–New Guinea differ in some important respects from those followed elsewhere. A comprehensive account has been published by Henderson (1954) but, since this may not be generally available, a brief description of the common practices will be given.

The cacao is of the Trinitario type and the trees are raised from seed which may be planted at stake or transplanted from baskets; the latter practice is followed where the giant snail (*Achatina fulica*, Fér.) may cause damage to young seedlings. The trees are usually spaced 15 ft apart on the triangle beneath the shade of the leguminous tree *Leucaena glauca*, Benth., which is planted in rows some months before the cacao. Cacao is also interplanted under coconut palms, which are generally spaced 30 ft apart, and the shade provided by the palms may be supplemented with *Leucaena glauca*. Plants such as papaw and breadfruit are never grown among the cacao trees. The recommended practice is to harvest pods at intervals of two to three weeks.

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MATERIALS AND METHODS

Sporangia of *Phytophthora palmivora* to be used for inoculation were obtained by growing the fungus on surface-disinfected cacao pods. In this way all other fungi were excluded from the inoculum and it was a simple matter to maintain such cultures by transfer of inoculum to fresh pods before secondary fungi could develop. This method was used because of the sparse production of sporangia on agar media. The same procedure was used to produce conidia of *Botryodiplodia theobromae* and *Colletotrichum* sp.

Inoculations were performed by preparing a suspension of sporangia or conidia in sterile tap water and applying this to the pod, with or without wounding as specified in the text.

Incubation was carried out in polythene bags or humidity cabinets; drier atmospheres were achieved by using airtight cabinets and suitable desiccants.

An arbitrary distinction was made between cherelles and pods, the latter being considered to exceed 10 cm in length. In order to describe the condition of the pods the following terms were adopted:

Immature: more then 10 cm long, but not of full size

Mature: approximately full size, but not ripe

Ripe: pods which would normally be harvested.

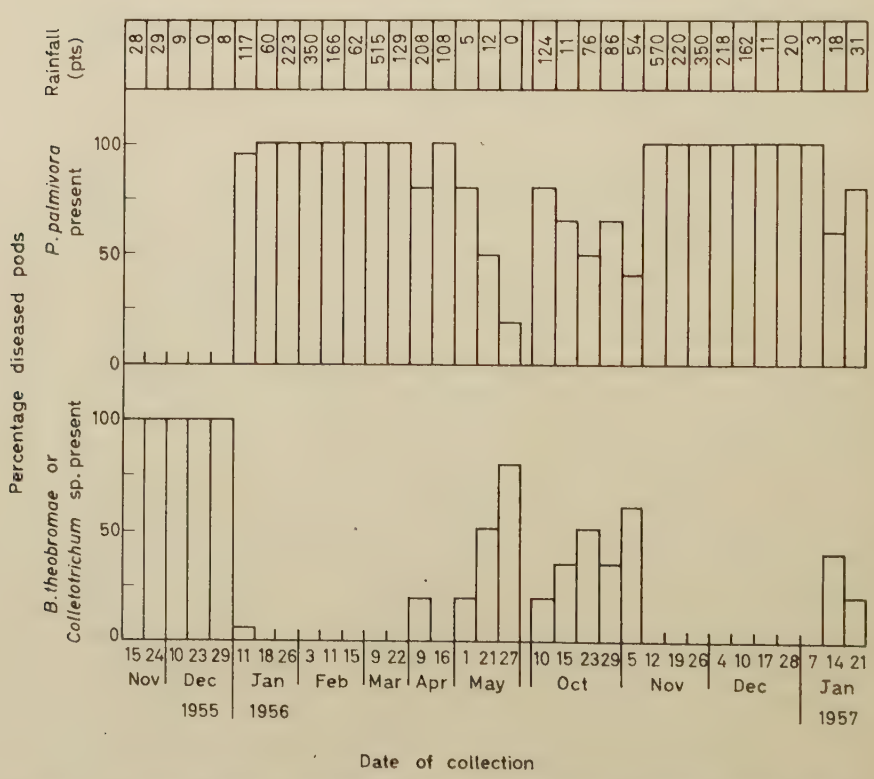

Figure 1. Relationship between occurrence of fungi on cacao pods and the rainfall recorded during a period of five days ending three days before the date of collection

FUNGI ASSOCIATED WITH POD ROTS OF CACAO

An estimate of the losses of cacao due to pod diseases and damage was obtained by making observations on 72 marked trees from 23 November 1955 to 8 May 1956. During this period, which corresponded closely to the wet season, the yield of ripe, healthy pods was 1 213, while the number of diseased pods due to all causes except obvious destruction by parrots, was 1 039; thus, 46 per cent of the total pods were lost before harvesting.

Diseased pods were collected at weekly intervals from other trees on the Experiment Station and isolations were made from them. The fungi that appeared were identified and the results are presented in *Figure 1*.

There was significant positive correlation ($r = +0{\cdot}58$, d.f.$=31$, $P=0{\cdot}010$) between the percentage of diseased pods upon which *P. palmivora* was present and the rainfall recorded during the preceding period. Hence, as it appeared in the Gazelle Peninsula during the period under consideration the disease referred to as 'black pod' consisted of two components: the wet-season component with which *P. palmivora* was associated, and the dry-season component from which *P. palmivora* was absent, but with which *B. theobromae* and *Colletotrichum* sp. were associated. Further evidence that 'black pod' consisted of two components was obtained from observations made on trees in comparable shaded and unshaded blocks. Eleven observations were made at intervals of about three weeks during the period 11 June 1956 to 8 January 1957, and the correlation coefficient was calculated between several pairs of variables for the two blocks.

Table 1. Statistical analysis of data, shaded and unshaded trees

Variables	*r*	*d.f.*	*P*
Total yield in shaded block: unshaded block	0·92	9	0·001
% diseased pods in shaded block: unshaded block	0·42	9	0·1
% diseased pods in shaded block: rainfall	0·45	9	0·1
% diseased pods in unshaded block: rainfall	−0·0099	9	0·1

McLaughlin (1950) has suggested that names for pod rots which are based on colour of the diseased pod are insufficiently accurate, and that each disease should be distinguished by the name of the fungus that is associated with it. Accordingly, the terms 'Phytophthora pod rot' and 'Diplodia pod rot' will be used.

PHYTOPHTHORA POD ROT

The causal fungus

One hundred sporangia from pods in an advanced stage of the disease were measured. The range of dimensions was $30 \times 21{\cdot}6$ microns to 56×37 microns, with an average of $42{\cdot}6 \times 27{\cdot}6$ microns. These dimensions fall within the range given by Tucker (1931) for *Phytophthora palmivora* Butler and correspond closely to the measurements recorded by Ashby (1929), though the length/width ratio (1·55) is lower than any recorded by him for sporangia on cacao pods.

Isolation of P. palmivora *from soil and pod heaps*

Instances of healthy pods becoming infected when soil was used as a source of inoculum have been reported by Orellana (1954). There has

also been some controversy concerning the importance of heaps of broken pods as sources of infection.

Healthy pods were placed upon or partially buried in old pod heaps (disused for nine months), current heaps and pod-free soil. None of the pods placed in soil that was entirely free from pod remains became infected with *P. palmivora*; those placed in contact with pod remains all became infected, but the number of foci of infection per pod was greater in the current heaps than in the disused ones.

Site of infection

DADE (1927) drew attention to the high proportion of pods in the Gold Coast (Ghana) which showed proximal infection, and suggested that diseased cushions probably accounted for a proportion of the infections occurring at this site.

In *Table 2* observations on 200 pods from New Britain are compared with Dade's results and with values obtained by THOROLD (1955) in Nigeria.

Table 2. Site of infection by P. palmivora

Locality	*Proximal*	*Distal*	*Lateral*
New Guinea	46%	31%	23%
Gold Coast	65·2	10·8	24
Nigeria	14·3	47·7	38

With respect to the site of infection, the pods collected in New Britain are intermediate between those from Nigeria and the Gold Coast. Slightly less than half of the pods, on which *P. palmivora* was definitely present, began to rot at the proximal end. However, the stalk was nearly always found to be healthy so that there was no evidence for migration of the pathogen from the cushion under field conditions.

Diseased flower cushions were extremely rare in the field and, in order to investigate the 'cushion canker' caused by *P. palmivora*, cushions of trees in the field were inoculated by cutting small wedges of tissue from them, painting the cut surface with a suspension of sporangia, replacing the wedge and covering the wound with grafting mastic. A mature pod was present on each cushion. The trees were examined at intervals for 24 days after inoculation.

Eleven of the twelve inoculated cushions developed symptoms of canker, and the pods on six of the cushions developed Phytophthora pod rot at the proximal end via the pedicel. Despite the severe nature of the wound, the cushions were only partially affected and after a few months the cankered region had been effectively sealed off from the rest of the cushion.

Natural resistance

A report has appeared (SMITH, 1955) of marked variation in the resistance of pods from different trees to infection by *P. palmivora*. Such resistance would be a very desirable quality in trees selected as sources of seed or of material for vegetative propagation, and it would be advantageous if a laboratory test were available by means of which field resistance could be accurately assessed.

Since 1946 a number of potential mother trees have been selected, the main criterion being yield of ripe pods. Yields had been recorded for several years and, for a period of about twelve months, the number of diseased pods was also recorded for certain mother trees. In this way, some knowledge of the field resistance of the mother trees was obtained and this information was used to determine the validity of laboratory tests for resistance.

The method adopted was based on that described by SMITH (1955). Ten uniform, mature pods free from wounds were selected from each tree to be tested. They were washed in tap water and the freshly cut ends of the pedicels were covered with grafting mastic. Inoculation was carried out by painting a suspension of sporangia along the three uppermost grooves. During incubation the pods were examined periodically and divided into five classes on the basis of their reaction. Criteria used to assess field resistance and laboratory resistance are presented in *Table 3*.

Table 3. Reaction of cacao pods to P. palmivora

Category	*Field resistance*	*Laboratory resistance*	
	% total pods diseased during 12 month period	*% pods showing infection after 3 days*	*Fraction of pod surface affected after 8 days*
V. resistant	0 – 5	0	*All pods* $< \frac{1}{4}$ *affected*
Resistant	6 – 10	1 – 25	$\frac{1}{4} - \frac{1}{2}$
Intermediate	11 – 20	26 – 50	$\frac{1}{2} - \frac{3}{4}$
Susceptible	21 – 40	51 – 75	$> \frac{3}{4}$ *and some sporing*
V. susceptible	41 – 100	76 – 100	*All pods completely affected, with dense sporing*

The results presented in *Table 4* show that the degree of resistance as assessed by this method bears a good relationship to field resistance so that the method would be useful in testing the resistance of potential mother trees.

Generally, those pods on which infection was delayed (i.e. showing resistance to initial infection) also showed resistance to extension of the disease.

Table 4. Resistance of pods to infection by P. palmivora

Mother tree	*Field resistance*	*Laboratory resistance*
K6	*V. resistant*	*V. resistant*
K51	*Resistant*	*V. resistant*
K5	*Resistant*	*Resistant*
K20	*Intermediate*	*Intermediate*
K15·101	*Intermediate*	*Intermediate*
K27·102	*Intermediate*	*V. susceptible*
K23·104	*V. susceptible*	*Intermediate*
K23·102	*V. susceptible*	*V. susceptible*
Unselected J	*Unknown*	*Intermediate*
Unselected F	*Unknown*	*V. susceptible*
Unselected G	*Unknown*	*V. susceptible*

Control by removal of diseased pods

A method of controlling pod diseases that has been widely advocated is the removal of diseased pods at each harvest, the pods being left on the ground to rot.

In theory, such a procedure should reduce the number of new infections due to contact and splash. However, the possibility exists that pods on the ground continue to act as sources of infection, and some experiments were carried out to investigate this possibility.

Pods were selected which were about half-rotted and on the surface of which abundant sporangia of *P. palmivora* were present. Some pods were marked and left on the trees, others were cut off and placed on the ground, while a third group was removed and placed on the laboratory bench. At intervals the pods were examined for the presence of viable sporangia of *P. palmivora.*

Table 5. Condition of pods

Site	*Days from beginning of experiment*		
	4	8	13
On tree	*Heavy overgrowth. Abundant sporangia*	*Heavy overgrowth. Abundant sporangia*	*Some viable sporangia*
On ground	*Few sporangia*	*No sporangia*	*No sporangia. Pod desiccated*
In laboratory	*Abundant sporangia*	*Few sporangia. Saprophytic fungi present*	*Pod completely desiccated*

P. palmivora could be isolated after 8 days from the tissue of pods left on the ground, and after at least 13 days from those on the trees.

The rapid disappearance of sporangia from the surface of pods on the ground was found to be due to the activities of the small snail *Subulina octona*, Brug., which is normally found in large numbers among the rotting cacao leaves. After being on the ground for two hours, pods with dense masses of sporangia upon them had an average snail population of 40 per pod compared with 3 per healthy pod; after 31 and 55 hours the populations were 55:7 and 13:12 respectively. After 55 hours the infected pods were almost free from overgrowth of *P. palmivora*, and thereafter the snail population remained small.

DIPLODIA POD ROT

In *Figure 1* it was shown that *Botryodiplodia theobromae* Pat. and *Colletotrichum* sp. were associated with a disease of cacao pods during the dry season. These two fungi are usually considered to be only weak parasites (Briton-Jones, 1934).

Comparison of symptoms

The rots caused by *P. palmivora* and *B. theobromae* are quite distinct in appearance. Tissue which has been invaded by *P. palmivora* is light brown in colour when freshly cut. The wall of the pod remains firm and the diseased tissue is no drier than healthy tissue; the mucilage remains pale

in colour. Tissue invaded by *B. theobromae* is dark brown in colour and becomes drier than healthy tissue while the wall of the pod has a marked tendency to disintegrate. The mucilage is darker than normal and there is a characteristic musty odour when the pod is cut.

The three fungi, *P. palmivora*, *B. theobromae* and *Colletotrichum* sp. were inoculated on to pectate gel (Dowson, 1949). While *B. theobromae* grew well and caused some liquefaction of the gel in 18 days, the other two species were unable to grow at all. Thus, some of the differences between the rots caused by *B. theobromae* and *P. palmivora* are probably due to their relative abilities to break down the calcium pectate of the middle lamellae.

Experiments with B. theobromae

A number of inoculation experiments were carried out with wounded and intact, surface-disinfected pods. In most cases rotting, due to *B. theobromae*, began at places other than the point of inoculation, and usually at the base of the pod. For example, in one experiment 75 per cent of the pods began to rot at the base, while the remainder started at the point of inoculation. Accordingly, the possibility of latent infection was considered.

Healthy pods were surface-disinfected with 1:1 000 mercuric chloride, thoroughly washed with sterile water and placed in a sterilized cabinet. 75 per cent of the pods had begun to rot after 12 days and, in all instances, the rot developed most rapidly from the base, although other foci also appeared. There was close correlation between the development of the rot and loss of turgor by the pod; rotting did not begin until the pod had become slightly flaccid.

At the base of a cacao pod there is a deep depression around the point of insertion of the pedicel, and in this depression a good deal of debris collects. When debris from several pods was examined microscopically, conidia of *B. theobromae* were found in all instances; other easily recognized conidia were those of *Curvularia*, *Nigrospora* and *Pestalotiopsis*. Fragments of debris plated on malt extract agar gave rise to colonies of *B. theobromae*.

It was concluded that conidia of *B. theobromae* were constantly present on the surface of healthy pods, and particularly in the basal depression, but that the organism was able to develop and rot the pods only when the resistance of the pod was reduced.

Consequently, groups of pods were subjected to treatments which would induce loss of turgor (e.g. placing in desiccator cabinets with calcium chloride, placing in direct sunlight). These treatments greatly favoured the development of *B. theobromae*.

Furthermore, when sets of pods were inoculated with *B. theobromae* and placed in 100 per cent humidity, 60 per cent of them remained turgid and healthy after 13 days, while all of a comparable set of pods that had been at 70 per cent relative humidity had begun to rot after the same period of time.

Similar observations were made with pods inoculated with *Colletotrichum* sp., except that development of the rot was slower than with *B. theobromae*.

DISCUSSION

From the foregoing account the fact clearly emerges that the condition referred to as ' black pod ' in the Gazelle Peninsula of Papua–New Guinea can be attributed to two causes. There is a wet-weather component of the disease for which infection by *P. palmivora* is directly responsible and which may therefore be designated ' Phytophthora pod rot '. In addition there is a dry-weather component, the cause of which is more complex but which involves the development of *B. theobromae* or *Colletotrichum* sp. on pods with a lowered resistance; for convenience this condition may be termed ' Diplodia pod rot '.

It has been shown that conditions which induce loss of turgor by the pod, or damage to the pod, favour the development of *B. theobromae* and *Colletotrichum* sp. Such conditions would prevail during a prolonged dry season, so that pods would be lost to Diplodia pod rot.

Statistical analysis of data for shaded and unshaded cacao blocks revealed that while there was significant positive correlation between total yield of pods in the two blocks, there was no such correlation between the occurrence of diseased pods. Furthermore, the occurrence of diseased pods in the two blocks was related differently to rainfall. It is postulated that, although Phytophthora pod rot and Diplodia pod rot were operative in both blocks during the appropriate seasons, the former was more important in the cooler, more humid conditions of the shaded blocks, while Diplodia pod rot was favoured by drier conditions in the unshaded block.

McLaughlin (1950) has stated that Diplodia pod rot in Ecuador is seen only on over-ripe pods and could probably be checked by timely harvesting. The evidence from New Guinea indicated that Diplodia pod rot develops only on pods with decreased resistance. Consequently, measures for control of the disease can be resolved to cultural practices such as frequent harvesting, avoidance of wounding unripe pods, and provision of adequate overhead shade during the dry season.

Rubber, papaw and coconuts have often been recorded as hosts of *P. palmivora* in tropical countries. An example of bud-rot of coconuts with which the fungus was associated has been reported from New Guinea by Dwyer (1953), but natural infection of other hosts has not been seen.

Inoculation experiments with wounded, green papaw fruits and the leaves and wounded stems of rubber showed that the strain of *P. palmivora* isolated from cacao was unable to infect these potential hosts.

Experiments reported by Ashby (1929) showed that cultures of *P. palmivora* isolated from various hosts existed in two well-defined strains, referred to as the ' cacao ' and the ' rubber ' strains, and that sexual reproduction occurred only when members of the different strains were grown together. It appears that the strain of *P. palmivora* commonly encountered on cacao in New Guinea is fairly specific to that crop and that the potential variability of the fungus is limited.

In contrast to the results reported by Orellana (1954), soil was not found to serve as a source of inoculum of *P. palmivora*. Sporangia of the fungus are readily wetted by water and are probably freely washed into the lower levels of the soil, particularly in one with such a light texture as that of the northern Gazelle Peninsula. Heaps of broken pods were a

potent source of inoculum even when no fresh shells had been added to them for nine months.

Although a high proportion of the pods with which *P. palmivora* was associated began rotting from the proximal end, there was no evidence that infection began from diseased cushions, and inoculation experiments showed that the cushions were very resistant to the strain of fungus common on cacao pods.

Field records and laboratory tests revealed that the pods of different trees varied considerably in their resistance to *P. palmivora*. In laboratory tests, most of the selected mother trees showed a higher degree of resistance than unselected trees chosen at random, and three of the mother trees possessed a high degree of resistance. It would appear, therefore, that when the mother trees were selected on the basis of the yield of ripe pods, they were automatically selected for a considerable degree of resistance.

There was a sound theoretical basis for the recommendation that cacao pods infected with *P. palmivora* should be removed and left on the ground as a control measure. Briton-Jones (1934) stated that pods left on the ground do not produce sporangia. The present results do not substantiate this statement, but they do show that sporangia disappear from the surface of pods on the ground much more quickly than from pods on the trees. Desiccation and invasion by saprophytic fungi were important in destroying pods on the ground and it was also noticed that the snail, *Subulina octona*, was very active in clearing sporangia from the surface of infected pods.

SUMMARY

' Black pod ' of cacao as it exists in the Gazelle Peninsula of New Britain has a component caused by *Phytophthora palmivora* which is positively correlated with rainfall (' Phytophthora pod rot '), and a dry-weather component from which *P. palmivora* is absent (' Diplodia pod rot ').

The strain of *P. palmivora* isolated from cacao was highly specific to that crop. Heaps of broken pods were an important source of inoculum of *P. palmivora*, but the fungus could not be detected in pod-free soil. Although 46 per cent of infections occurred at the proximal end of the pods, no evidence was obtained for infection from diseased cushions.

Pods obtained from different trees differed markedly in their resistance to *P. palmivora*; satisfactory agreement was achieved between laboratory tests of resistance and field resistance. Experiments showed that a sound theoretical basis exists for the recommended control measure of removing diseased pods at frequent intervals.

The cause of Diplodia pod rot is obscure, but it is probably due to diminished resistance of the pods, often associated with loss of turgor, which permits the development of weakly pathogenic fungi that are present on the surface of the pods.

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Observations on the Diseases of Cacao Pods in Papua–New Guinea—II

Cherelle Wilt

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In all countries in which cacao is grown the observation has been made that some of the fruit wilt and turn black while they are still very small. This condition, known as ' cherelle wilt ', has been attributed to a number of causes: competition for water (Humphries, 1943) or nutrients (Alvim, 1954), or deficiency of hormones produced by the endosperm causing a decrease in the uptake of water (McKelvie, 1956). Working in Costa Rica, Bartolomé (1954) and McLaughlin (1956) found that the condition was due to *Phytophthora palmivora* and an unnamed insect; McLaughlin stated that there was also a physiological wilt which occurred during periods of severe drought.

In view of these contradictory reports, the problem was investigated as it existed in the northern Gazelle Peninsula of New Britain, with particular reference to the existence of a ' pathological ' as opposed to a ' physiological ' component of cherelle wilt.

MATERIALS AND METHODS

Lengths of the lower branches of 52 mature trees were marked with paint and examined at intervals of approximately one week for 66 weeks; the cherelles that were present were classified into four categories with respect to length and described also as ' healthy ' or ' wilted '.

In the laboratory, the wilted cherelles were surface-disinfected, pieces of them were plated, and the fungi that appeared were identified. Cherelles which had become hard and black were not plated and, as a consequence, no results were obtained for cherelles less than 2 cm long.

Since comparatively few cherelles were obtained in this way, additional cherelles were collected on the same day from other trees; these were classified with respect to size and plated.

RESULTS

Size of cherelles at wilting

A total of 103 cherelles and small pods were collected from the marked trees in a wilted or diseased condition. *Table 1* shows the size distribution.

Table 1. Size of cherelles at wilting

Length (cm)	<2·0	2 – 5	5 – 10	>10
Number	61	27	8	7
Percentage of total	59	26	8	7

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Fungi present on cherelles

A total of 142 cherelles were collected from marked and unmarked trees over a period of 40 weeks, plated, and the fungi that appeared were identified; the lengths of these cherelles were measured to the nearest 0·5 cm (*Table 2*).

Table 2. Fungi present on wilted cherelles

Length (cm)	0 – 1·9	2 – 3·9	4 – 5·9	6 – 7·9	8 – 10
P. palmivora (*number*)	?	0	10	10	16
Other fungi (number)	?	26	38	29	13

Of these cherelles, 25 per cent gave rise to colonies of *Phytophthora palmivora*, while the remainder yielded colonies of *Botryodiplodia theobromae* or *Colletotrichum* sp. *P. palmivora* was not isolated from cherelles less than 4·0 cm long and was proportionately more abundant on larger cherelles.

In order to investigate the fungal flora of healthy cherelles and the progress of infection with wilting, various cherelles were collected, divided into classes and plated (*Table 3*).

Table 3. Fungi present on healthy and wilted cherelles

Description	*Number*	*Number remaining sterile*	*Fungal spp.*
Healthy	15	13	B. theobromae Colletotrichum *sp.*
Early wilting	7	0	Colletotrichum *sp.* *Some pieces remained sterile*
Advanced wilting	11	0	Colletotrichum *sp.*

Statistical analysis of the data

The correlation coefficient was calculated for several pairs of variables using the information obtained from marked trees and by plating the wilted cherelles (*Table 4*).

Table 4. Statistical analysis of data

Variables	*r*	*d.f.*	*P*
%*cherelles with* P. palmivora*: rainfall*	0·5017	37	0·01 – 0·001
%*wilted cherelles (total): rainfall*	0·1244	37	0·1
%*cherelles with* P. palmivora*:* %*wilted cherelles (total)*	–0·1016	36	0·1
%*wilted cherelles (total): total number of cherelles*	0·3017	55	0·02

% wilted cherelles (total) refers to both pathological and physiological components of cherelle wilt.

DISCUSSION

A pathological component of cherelle wilt, due to *Phytophthora palmivora*, accounted for 25 per cent of the wilted cherelles that were examined. The remaining 75 per cent of the cherelles were considered to have wilted through non-pathological or physiological causes.

When cherelles were inoculated with *P. palmivora* the symptoms were essentially similar to those produced in mature pods. *P. palmivora* was the

only fungus which consistently caused such symptoms when inoculated on to cherelles. The symptoms of ' physiological ' wilt and the disease due to *P. palmivora* were quite distinct. The first stage of physiological wilting was a loss of bloom by the cherelle. If the healthy cherelle were green in colour, it became in turn yellow-green, yellow and finally pale brown; the change in colour began at the proximal or distal end, but quickly involved the entire cherelle.

By contrast, infection by *P. palmivora* began at one or two places on the surface of the cherelle and, as the lesion enlarged, there was a sharp division between the uninvaded and diseased tissue. The uninvaded tissue appeared to be quite normal and retained its characteristic bloom for a time.

There was a clear distinction between the factors influencing the occurrence of the pathological and physiological components of cherelle wilt. The occurrence of pathological wilt was significantly correlated with rainfall, and in this respect resembled Phytophthora pod rot of mature pods (Thrower, 1960). There was no significant correlation between the percentage of cherelles that had wilted from both causes (total cherelle wilt) and rainfall, indicating that the physiological fraction was not associated with high rainfall, but was favoured by dry conditions (*Table 4*). In addition, the percentage of wilted cherelles was significantly correlated with the total number of cherelles that were present, whereas the occurrence of *P. palmivora* showed a negative correlation with the total number of cherelles; thus physiological wilt was most severe when the greatest number of cherelles were present. The counts made on marked trees revealed that the highest proportion of cherelles (59 per cent) wilted when they were less than 2·0 cm long (*Table 1*); this was probably a conservative estimate because it is likely that fruit could set, wilt and fall in less than the seven days which separated the observations.

When healthy cherelles were plated most of them remained sterile, but colonies of *B. theobromae* and *Colletotrichum* sp. developed from a few of the plated fragments. This result was interpreted to indicate latent infection of the cherelle or the presence of conidia which were firmly attached to its surface. By contrast, all pieces of brown, wilted cherelles gave rise to fungal colonies, showing that the fungus had thoroughly penetrated the tissue of the cherelles.

On the basis of these results, a hypothesis can be advanced to account for the symptoms of physiological cherelle wilt. The condition is considered to be due primarily to a decline in the water balance of the developing cherelle, with consequent loss of turgor. Thus, internal or external factors which restrict the supply of water to the cherelle or increase the rate of transpiration would favour the development of cherelle wilt. Such factors would include low rainfall and relative humidity, and a large crop of cherelles making heavy demands upon the tree.

As soon as the turgor, and resistance, of the cherelle declines, the fungi which are present in the latent condition can develop, quickly penetrate the entire tissue and bring about the characteristic change in colour. Thus, it is considered that fungi such as *B. theobromae* and *Colletotrichum* sp. develop only as a consequence of the impaired physiological condition of the cherelle.

Humphries (1943) was led by the results of his field studies to the conclusion that cherelle wilt in Trinidad was due primarily to deficiency of water and nutrients. He considered that competition for water between individual cherelles was important, as was competition between cherelles and flushes of young leaves. He did not obtain any evidence that weather had a direct effect on the occurrence of wilt.

The conclusions to be drawn from the results obtained in New Guinea for physiological cherelle wilt are thus essentially similar to those of Humphries.

SUMMARY

The condition referred to as ' cherelle wilt ' consists of a pathological component and a physiological component. *Phytophthora palmivora* is directly responsible for pathological cherelle wilt, which accounted for approximately 25 per cent of the total wilted cherelles. The epidemiology of this disease resembled closely Phytophthora pod rot of mature cacao pods.

Physiological cherelle wilt was most destructive to smaller cherelles (less than 2·0 cm long). Evidence is marshalled in support of the theory that it is associated with competition for water by the developing cherelles and other growing parts of the plant.

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A Progress Report on the First Six Years of a Pruning Experiment with Nyasaland Tea

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At the start of this experiment in 1951 Nyasaland had some 24 000 acres of tea and slightly more than half of this acreage was under a narrow-leaved variety called ' Hybrid ' or ' Local ' tea. The remainder, in contrast, was of much broader-leaved types grown originally from seed of known origin, usually imported from India. The early establishment of the tea industry in Nyasaland was made on the vast majority of estates with local tea, but later plantings and more recently replacement of old tea, were and are invariably made with Indian varieties. Economic considerations limit the pace at which old tea can be uprooted and the areas replanted with better varieties, and although the local tea will gradually disappear it is inevitable that a considerable acreage will remain for many years.

Before this experiment, practically all local tea was clean-pruned annually, receiving thereafter a two inch tip above the pruning cut and an annual application of nitrogenous fertilizer supplying on the average about 30 lb of nitrogen (N) per acre. In contrast Indian varieties were clean-pruned in alternate years or less frequently, received double the tipping height and not less than double the nitrogen rate per year allocated to the local tea. Indian varieties with this treatment yielded more than local tea. Planters nevertheless were of the strong opinion that local tea must be pruned annually and thereafter must receive considerably harder physical treatment than that given to Indian tea varieties if yields were to be maintained.

Much work has been published over the years on the pruning and tipping of tea and although pruning cycles vary in length or in type according to location, the general conclusion to be drawn from all these data is the importance of ensuring, by differing methods, adequate maintenance leaf on the bush between prunes. A concise review of pruning methods with a list of references to the more important papers has been given by Eden (1958).

Nyasaland experience with poor types of narrow-leaved Indian tea, unshaded with permanent shade trees, had shown positive responses in yield to two- or three-yearly pruning cycles over an annual prune and positive responses both in yield and in the weight of maintenance foliage when given up to 120 lb of nitrogen per acre (Anon. 1955–56, 1956–57, 1957–58). No conclusive evidence was available on tipping height effects. Eden's work in Ceylon (1949) had indicated strongly that response to nitrogen increased with time away from prune and consequently the present

experiment, although primarily intended to observe the effects of three pruning cycles, had three nitrogen rates superimposed on the pruning and tipping treatments. This, as it has turned out, was a fortunate addition.

When it is remembered that tea of this type is to be cultivated for many years to come, the main interest in this experiment must be in long term yield trends; that cumulative effects can become significant after ten years or longer has been demonstrated on more than one occasion in the Far East and consequently this paper is only intended to present a progress report covering the first six years.

EXPERIMENTAL DETAILS

An area of unshaded tea, planted about 1914, and spaced at four feet square was chosen for the experiment at Thornwood Estate in the Mlanje district. A calibration trial occupied the 1951–52 cropping season after which all plots were clean-pruned to a standard height of 18 inches above ground level at the start of experimental treatments in July 1952. The crop year is taken from July to June, the main rains being from mid-November to the end of April.

Three sets of main treatments, each at three levels, are included in two complete replications of a 'three-cubed' factorial design; treatment combinations are arranged in blocks of nine plots so that the three factor interactions are partially confounded. Plots are ten bushes by fourteen bushes long with the longer axis pointing down-hill (LAYCOCK, 1955). Main treatments compared are:

p_0 clean-prune annually
p_1 clean-prune every second year
p_2 clean-prune every third year

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t_0 tipped to form the new plucking table at 2 in. above pruning cut
t_1 tipped at 4 in.
t_2 tipped at 6 in.

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n_0 sulphate of ammonia supplying 40 lb nitrogen per acre per year
n_1 sulphate of ammonia supplying 80 lb nitrogen
n_2 sulphate of ammonia supplying 120 lb nitrogen.

All plots received in addition, 30 lb phosphorus pentoxide (P_2O_5) and 30 lb potassium oxide (K_2O) per acre per year as single superphosphate and muriate of potash. All fertilizers are applied in early November (LAYCOCK, 1957a).]

The tea is plucked and pruned by estate labour but supervision, recording and placement of treatments is carried out by the station staff. Throughout the main crop season plucking usually takes place at weekly intervals, although during the early part of 1956–57 acute labour shortages resulted in considerably longer intervals and caused an increase in the standard error for that season.

At the end of the 1957–58 season all plots were clean-pruned, there having been since 1951–52, six one-yearly, three two-yearly and two three-yearly pruning cycles. Immediately after this prune, sample measurements were made on wood growth within the bared frameworks to assess the cumulative effect of treatments over the previous six years. The declared objects of clean-pruning as practised in this experiment are to cut branches off at half an inch above the previous cut, thereafter removing

any dormant and dead branches and reducing any interlacing clusters of branches so that only the stronger are left standing free. These objects are typical of estate practice and easy to declare but bushes and men are inherently variable and pruning of this type becomes a matter involving subjective skill. In order to reduce skill effects as much as possible or practicable, a gang of fourteen workers were used consistently throughout each pruning season and each man prunes one row across the width of each plot offering thereby theoretically equal amounts of skill over all the plots pruned in any one season.

Preliminary measurements on wood growth showed that it was beyond the time and resources available to measure each and every branch in the whole experiment. Sample measurements had thus to be taken, unfortunately without the aid of previous experience from a proven sampling technique for this type of work. One complete longitudinal row (i.e. at right angles to pruning direction) was chosen at random in each plot, and across the top of the row and over the centre of the bushes two strings were stretched and held apart by 1 ft spacer boards. The distance between the extreme outside branches within the strings was taken as a measure of spread of the frameworks and the diameters at the cut ends of all the branches enclosed by the strings were recorded to the nearest 1/16 in. by a method developed previously for measuring stump diameters (LAYCOCK, 1957b). The height of the pruning cut above soil level was measured in the centre of the framework.

RESULTS

Yields in pounds of made tea per acre according to main treatments are recorded in *Table 1* for each season and for total yields averaged over the six years. Asterisks denote the season immediately following prune.

Table 1. Yield in lb made tea per acre according to main treatments

Season	*Pruning cycle*			*Tipping height*		
	1 yr	*2 yr*	*3 yr*	*2 in.*	*4 in.*	*6 in.*
1952–53	1 190*	1 194*	1 237*	1 250	1 195	1 177
1953–54	1 016*	802	838	915	883	858
1954–55	1 054*	1 094*	867	1 033	1 002	980
1955–56	1 209*	1 037	1 467*	1 299	1 230	1 184
1956–57	1 029*	1 305*	1 125	1 193	1 140	1 126
1957–58	839*	802	706	824	781	796
Mean for 6 years	1 065	1 039	1 040	1 085	1 039	1 020
Season	*Fertilizer lb nitrogen/acre*			*L.S.D.*		
	40	80	120	*P*=0·05	*P*=0·01	*C.V.*%
1952–53	1 066	1 218	1 338	107	146	12·85
1953–54	709	878	1 069	82	111	13·32
1954–55	801	1 004	1 210	116	158	16·75
1955–56	929	1 239	1 545	105	143	12·26
1956–57	739	1 150	1 570	196	266	24·59
1957–58	519	795	1 087	98	134	17·74
Mean for 6 years	794	1 047	1 303	108	147	14·84

Significant differences due to pruning cycle occur between seasons according to the comparative times away from prune but average yields for the six seasons show no significant losses in cumulative crops by extending the cycle from one to two or three years.

Losses in crop caused by raising the tipping height occur in every season but in no year have they reached significance. In most years the pruning cycle times tipping height interaction reached significance but this is primarily due to the experimental design whereby not all treatments are pruned and hence tipped in any one season after the first.

Nitrogen invariably caused significant increases in crop.

More interesting and more important than the main treatment yields are those given in *Tables 2* and *3*. Starting with the third season there were indications that a pruning cycle times nitrogen rate interaction was building up and in the sixth season the linear times linear component reached significance at $P=0{\cdot}05$, accounting for 85·07 per cent of the sums of squares for the interaction. It has not reached significance for the six-yearly average yields but as might be expected the sums of squares due to the interaction is slowly increasing.

Table 2. Interaction of length of pruning cycle and nitrogen rate for the season 1957–58. Yields in lb made tea per acre

Pruning cycle	*lb nitrogen/acre*			*Mean for cycle*
	40	80	120	
1 yr	688	898	1 095	893
2 yr	511	769	1 126	802
3 yr	357	718	1 042	706
Mean for nitrogen	519	795	1 087	

Table 3. Interaction of length of pruning cycle and nitrogen rate. Average yield per season for the six seasons

Pruning cycle	*lb nitrogen/acre*			*Mean for cycle*
	40	80	120	
1 yr	867	1 053	1 275	1 065
2 yr	788	1 029	1 299	1 039
3 yr	726	1 056	1 337	1 040
Mean for nitrogen	794	1 047	1 303	

It is apparent from these tables that the low nitrogen rate is not supporting longer cycles to their optima.

The returns in pounds of tea for each added pound of nitrogen have varied between seasons and between ages from prune as can be seen in *Table 4* and, in general, higher returns have been recorded from unpruned tea.

The measurements made on the frameworks at the end of the first six years have been averaged on to a single bush basis and are presented according to main treatments in *Table 5*.

There are no significant interactions between treatments for any of these characteristics.

Table 4. Returns in lb made tea for each added pound of nitrogen

Season	Treatment	Years from prune	Response lb tea per lb nitrogen from N40 to N80	from N80 to N120
1952–53	p_0	1	3·72	2·97
	p_1	1	3·60	2·93
	p_2	1	4·07	3·10
1953–54	p_0	1	2·62	3·73
	p_1	2	5·10	5·08
	p_2	2	5·03	5·50
1954–55	p_0	1	3·67	4·91
	p_1	1	3·72	4·93
	p_2	3	7·85	5·51
1955–56	p_0	1	7·00	7·70
	p_1	2	7·12	7·83
	p_2	1	9·11	7·52
1956–57	p_0	1	7·00	7·72
	p_1	1	11·12	9·75
	p_2	2	12·68	14·12
1957–58	p_0	1	5·25	4·93
	p_1	2	6·45	8·92
	p_2	3	9·03	8·10
Mean for 6 seasons	p_0	—	4·65	5·50
	p_1	—	6·03	6·75
	p_2	—	8·25	7·03
	Main effect	—	6·32	6·41

Table 5. Effect of main treatments on various characteristics of the framework

Factor	Pruning cycle			Tipping height		
	1 yr	2 yr	3 yr	2 in.	4 in.	6 in.
Pruning height, in.	21·61	19·70	19·42	19·64	20·38	20·71
Area sampled, in²	464	450	430	460	449	435
Mean no. of branches in sample area	18·7	20·6	22·3	21·6	21·2	18·8
Stem diameter, in.	0·26	0·29	0·34	0·28	0·30	0·31
Total stem surface area, in²	1·05	1·55	2·14	1·52	1·59	1·63

Factor	lb nitrogen/acre			L.S.D.		C.V.%
	40	80	120	P=0·05	P=0·01	
Pruning height, in.	20·30	19·94	20·49	0·99	1·35	7·09
Area sampled, in²	427	458	459	19	26	6·10
Mean no. of branches in sample area	18·8	20·8	22·0	2·0	2·7	14·15
Stem diameter, in.	0·28	0·30	0·31	0·01	0·02	7·15
Total stem surface area, in²	1·30	1·66	1·78	0·15	0·21	13·64

In view of the lack of established sampling technique the standard errors of the analyses, expressed as a percentage of the mean (C.V.%) are gratifyingly low and compare favourably with the standard errors of the yield analyses.

Lengthening the pruning cycle has reduced the pruning height as would be expected, because less frequent pruning must mean a slower rise because of the infrequency of the physical treatment given. The increase in pruning height between the 2 and 6 in. tips is just significant at $P=0{\cdot}05$ and this is unexpected and perhaps fortuitous. Increasing nitrogen rates have not significantly affected pruning height.

The mean area sampled per bush was calculated by multiplying the 12 in. space between the strings (constant over all treatments), by the distance between the extreme outside branches within the strings (variable according to treatments). Lengthening the cycle and increasing the tipping height have significantly decreased the sampled area whereas an increase in nitrogen rate from N40 to N80 has significantly increased the area but there is no further significant increase caused by further addition of nitrogen from N80 to N120.

The mean numbers of branches in the sampled area were obtained by direct averaging of the numbers of stem diameters measured and have been significantly affected by treatments. Increasing the tipping height has decreased the numbers whereas lengthening the pruning cycle and increasing the nitrogen rate have had opposite effects. A tailing-off in effect occurs between the two higher nitrogen rates.

Increasing rates of all main treatments have caused significant increases in mean stem diameters.

The total surface area of the cut stems was calculated directly from the individual branch diameters and then averaged to a single bush basis. Increasing rates of all main treatments have caused increased surface areas to be developed, the most pronounced effect being due to pruning cycle.

In order to examine any correlation between total crop harvested and frame characteristics developed over the six seasons, the above variables were used together in a multiple regression calculation using yields and wood characteristics from each of the separate 54 plots in the experiment. Only the components due to sample area and numbers of branches reached significance and consequently a simpler function using these two variables was calculated, thus

$$Y=4{\cdot}9500\ A+44{\cdot}0020\ N-2081$$

where Y denotes mean yield per year per acre for the six years, A is the area sampled, and N the number of branches in the sampled area.

This function accounts for 62·56 per cent of the total sums of squares of yield, leading to a correlation coefficient of actual yield against calculated yield of $+0{\cdot}7910$ which is significant at $P=0{\cdot}001$. The addition of the other variables in the full multiple regression caused an increase of slightly less than two per cent of the yield sums of squares accounted for by the simpler function.

DISCUSSION

Although it would be unwise to draw definite conclusions at this early stage in the life of the experiment one lesson has been learned and that

concerns experimental design. In an experiment of this sort a quantitative understanding of yields, yield trends and responses in relationship to treatments should be elucidated. Reference to the seasonal yields due to annual prune in *Table 1* shows wide seasonal variation which is considered to be mainly due to climate differences. With the longer cycles the between-season variation in yields for any one cycle must in part be due to climatic effects and in part due to length of time away from prune. This latter part is likely to have a non-linear effect on yield patterns [EDEN, 1946; ANON. (Kericho), 1956; ANON., 1952–53]. Variation in response to treatments as opposed to yield *per se*, for example returns for each pound of added nitrogen as given in *Table 4*, might be expected to reflect an interplay of climate and cycle effects. Although the field management methods forming the main treatments in this experiment are under direct control there is no provision for overcoming or accounting for seasonal climatic effects which are very variable in Nyasaland, other than by the use of long-term data—replication in time. This method in itself is unlikely to lead to an uncomplicated examination of data because, for example, the slow building up of the pruning times nitrogen rate interaction appears to indicate that replication in time is also introducing a trend likely to be of significance for this pair of treatments at least.

A more elegant design, which should do much to smooth out the effects of inter-seasonal climatic differences and consequently make interpretation of data more direct and less complicated, would be to phase pruning cycles so that all stages of any cycle would be represented in any one year.

The cumulative interplay of pruning cycle length and nitrogen rate illustrated by this experiment offers a general warning for the questions to be asked in long-term field experiments with tea. When it is borne in mind that mature tea is under routine subject to differing field management methods which can be classified broadly under pruning, tipping, nutrition, spacing and permanent shading, it becomes evident that only complex experiments designed to question the interplay of these diversified methods, will offer answers of fundamental and practical importance.

The practical result of immediate importance is that due to the interaction of pruning cycle and nitrogen rate which brings into focus the early experience of estates and the consequent prejudice against extended cycles for local tea, when it is remembered that the custom was to apply between 20 and 40 lb nitrogen per acre per year to this type of tea. *Tables 2* and *3* demonstrate that a loss of crop would be expected in those circumstances. At present prices, the cost of applying an extra 40 lb nitrogen per acre approximately equals that of pruning but there is little doubt that the expense of the extra nitrogen is more than counterbalanced by the profit from the extra crop. A positive benefit is obtained from the denser foliage on the unpruned tea in terms of weed suppression and considerably reduced costs on weeding. With tea pruned on a three-yearly cycle total weed growth throughout the cycle is inversely proportional to the nitrogen rate applied (ANON., 1955–56b; EDEN, 1949).

It was reported above that the height of forming the new plucking tables above the pruning cut, the tipping height, has not so far significantly affected total yields, but it would be wrong at this early stage to draw definite

conclusions from this result.

Averaged over all pruning cycles and tipping heights for the six years, this tea has returned 6·32 lb of made tea for each added pound of nitrogen from 40 to 80 lb/acre and 6·42 from 80 to 120 lb. *Table 4* suggests that nitrogen efficiency increases with time away from prune, and averaged over the six seasons the responses obtained from the two-yearly cycle are about 25 per cent higher than those from the annual cycle, and the three-year cycle has increased responses by about 50 per cent in similar comparison. The reason for this is not known and is likely to be complicated, being dependent in some part on the pruning cycle times nitrogen rate interaction. EDEN (1949) suggests that the larger leaf area developed in the unpruned bush provides a more efficient mechanism for uptake of nitrogen from the soil and a larger metabolic area thereafter for synthesis. Another possible factor appears to warrant investigation. Soil moisture investigations under closely allied conditions to those in this experiment show that unpruned tea causes considerable drying of soil down to ten feet below the soil surface which is the deepest layer sampled (ANON., 1957–58). On the other hand pruning conserves soil moisture. Consequently the soil under the extended cycles in their unpruned years can be expected to dry considerably each dry season in the top ten feet at least. Annually pruned tea or extended cycles immediately following prune will conserve moisture at or near to field capacity until such time as the new leaf canopy develops. Thereafter drying commences and may or may not reach wilting point at all depths depending upon the earliness of the new rains. It would be of great interest to have data on soil nitrogen status under the three pruning cycles in the light of BIRCH and FRIEND's work on East African soils (1956) and BIRCH (1958) and to estimate therefrom whether or not the apparently increased efficiency of nitrogen in the unpruned years is in some part due to a proportionately higher available soil nitrogen content induced by soil drying over and above that nitrogen added by the fertilizer. In this connection it is perhaps of interest to record that other empirical investigations have shown that the seasonal yield of tea pruned on a three-yearly cycle, suitably phased over seasons, is negatively correlated with dry season rainfall (LAYCOCK, 1958).

Of the framework characteristics developed over the six years, area and the numbers of branches are the two variables with which total yield is significantly correlated. The lack of correlation with mean stem diameter or total surface area of stems within the sampled area is a result that would cause most Nyasaland planters surprise. A significant correlation is not in itself a measure of cause and effect, but the implications are sufficient to suggest room for further experiment with differing types of prune designed to influence area and the numbers of branches. Should the correlation be increased in importance by subsequent direct experimentation then the practical impact on field methods would be important in that the traditional skilled and expensive clean-prune might give way to a cheaper and less skilled cut-across type of prune (perhaps at the same vertical intervals) which can be expected to increase both the area of the frameworks and the numbers of branches. The implications for mechanical pruning are apparent.

It is of interest to note that only nitrogen has consistently increased all the factors measured in the framework but there is a tendency for the effect to be reduced above 80 lb nitrogen/acre. This bears out under Nyasaland conditions what has been pointed out on a number of occasions in the Far East, that nitrogen does not merely result in increased leaf yields but also affects the development of the bush as a whole.

SUMMARY

Results are given for the first six years of a three-cubed factorial experiment comparing three pruning cycles, three tipping heights and three nitrogen rates. No significant differences in total yields for the six years were caused by pruning cycles or by tipping heights but increasing nitrogen rates caused significant increases in yield.

An interaction between length of pruning cycle and nitrogen rate is slowly increasing in importance and is indicating that longer cycles require higher nitrogen to support them to their optima. Estate experience held that local tea, as used in this experiment, must be pruned annually if yields were not to fall. This experience is now explicable because the commonly used nitrogen rate was as low or lower than that which failed to support extended cycles in the experiment and led to the formation of the interaction.

Main treatments have had various effects on the framework characteristics measured but only nitrogen consistently caused increases and these tended to fall off between the two higher rates. Of these characteristics, area and numbers of branches were found to be significantly and positively correlated with total crop. Although a multiple correlation is not a sign of cause and effect, the implications are strong enough to suggest further direct experimentation.

The design of this experiment is not one that allows yield trends or responses to be quantitatively assessed without freeing them from the interplay of climatic effects which are very variable in Nyasaland. A better design would have pruning cycles so phased that all stages of each cycle were represented in any one year.

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Productivity of Pasture in British Honduras—I

Natural Pasture

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A pasture or *potrero* in British Honduras would hardly warrant such a name in any more advanced territory. Most of the existing ' pastures ' were established by cutting lines around an area of forest and erecting a fence: cattle were allowed to run in the area and graze on bush leaves and twigs. Eventually grass established itself naturally in the thinning underbrush, until after some years only the large trees remained. For many years the carrying capacity of such pasture is very low, particularly in the dry season. However, the vast majority of grazing land is of this type, and it was felt that the first step in pasture improvement was to evaluate this natural pasture and to decide whether and how its production could be economically improved. Both the experiments described here were carried out in the Western District of British Honduras.

(a) central farm (department of agriculture)

Experimental procedure

The pasture used for the experiment consisted of a natural sward with scattered shade and economic trees. It was near an old village site and so had experienced grazing by various cattle, horses, geese, etc. For four years previous to the experiment it had been grazed by beef cattle. During the period of the experiment it was grazed periodically by beef cattle and bush-hogged (rotary mown) when weed growth necessitated it.

Plots were 0·02 acre each and measurements were made at the end of each month with paired wire cages, 10 ft × 3 ft, which were laid down after each clipping on freshly clipped, randomly selected sites within the plot.

Fertilizer treatments were as follows:

C—Control

N—100 lb/acre sulphate of ammonia (21 per cent nitrogen) in May and again in November

P—100 lb/acre triple superphosphate (46 per cent phosphorus pentoxide) in May

2P—100 lb/acre triple superphosphate in May and again in November.

The areas beneath the cages were clipped and fertilizer applied at the end of May 1954. The first growth measurement was made at the end of June 1954. The trial was continued until the end of May 1956 to complete 24 months of records.

Table 1. Natural pasture—Central Farm. Yield (lb d.m./acre month). June 1954 to May 1956 (2-year averages)

Month	Fertilizer C	N	P	2P	NP
Jan	688	817	978	1 186	929
Feb	337	378	767	531	480
Mar	145	172	207	306	410
Apr	35	74	234	254	289
May	626	954	870	709	869
Jun	1 818	1 365	2 135	2 285	2 278
Jul	1 272	1 441	1 676	1 434	1 551
Aug	808	651	821	659	703
Sep	1 403	1 195	1 583	1 370	1 521
Oct	922	930	1 533	1 334	1 261
Nov	655	934	411	1 945	683
Dec	355	353	300	362	295
Annual total	9 062	9 264	11 515	12 375	11 269
% yield in 'rainy season'	83	81	78	79	79

Yields

The yields during April and May 1955 were nil due to a very severe dry season which ended abruptly on 19 June. The yields for May and June depend upon the date of commencement of the rains: this event can occur at any date between about mid-May and mid-June. Grab samples were taken for dry matter determination and botanical analysis.

By 'rainy season' is meant that portion of the year, approximately five to six months, between the onset of the rains and the end of November.

The dry matter content was, of course, highest during the dry weather. In other words, the uneven yield distribution during the year is accentuated even more when expressed as fresh material. The mean dry matter content was 25 per cent.

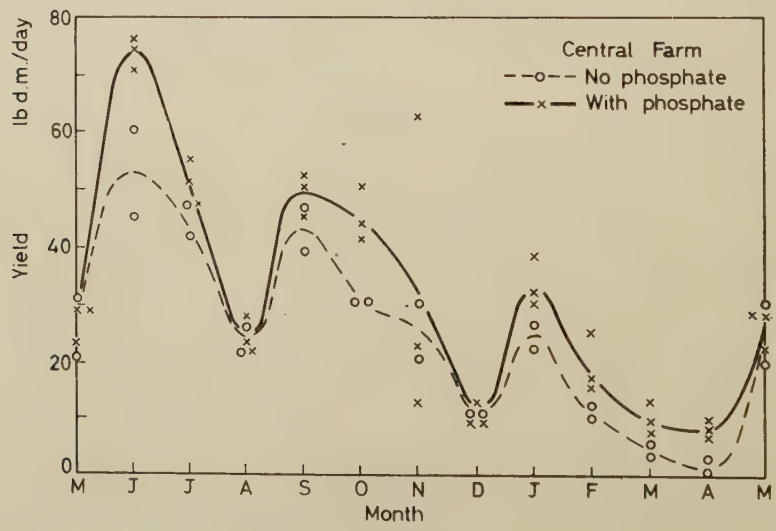

Figure 1. Yield of a natural pasture at Central Farm in lb d.m. per acre per day

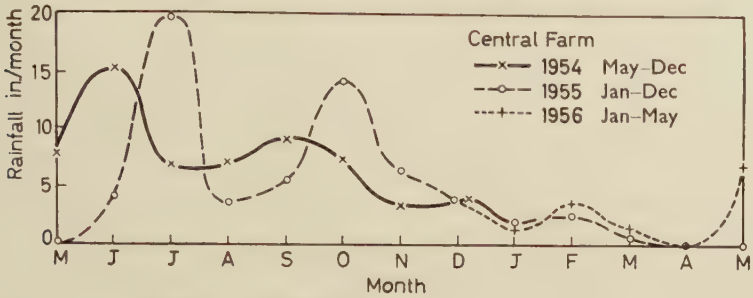

Figure 2. Rainfall at Central Farm in inches per month

Yield curves

The letters along the abscissa (*Figure 1*) represent the months of the year, and their position indicates the middle of the month. Since yields measured at the end of a month constitute the growth throughout that month, they are plotted to correspond with the middle of the month. Rainfall for any month (*Figure 2*) is similarly plotted to correspond with the middle of the month.

Botanical analysis

Axonopus compressus was the main graminaceous component of the sward at the commencement of the experiment, amounting to more than 50 per cent in the first year. In the second year it constituted approximately 20 per cent of the sward by fresh weight, its place being taken by weeds and crab grass.

Cynodon dactylon (Bahama grass) occupied 15 to 20 per cent of the sward without any noticeable change with season.

Paspalum centrale appears in the rainy season but has a low productivity in the dry season.

Crab grass (*Digitaria* spp., mainly *conjugata*) became much more prominent in the second year when it amounted to about 20 per cent of the total fresh

Table 2. Natural pasture—Central Farm. % Composition by fresh weight. June 1954–May 1956

Month	*Grasses*				*Weeds*	
	Axonopus compressus	*Crab grass*	*Bahama grass*	Paspalum centrale	*Chichebe*	*Others*
1954						
Jun	57	0	34	1	3	5
Jul	41	0	29	3	7	20
Sep	58	0	7	5	4	26
Nov	61	0	15	1	12	11
Dec	52	0	21	1	9	17
1955						
Jan	62	0	10	0	7	21
Mar	75	0	4	0	11	10
Apr	22	37	24	0	1	17
Jun	18	19	21	6	7	29
Aug	15	7	14	44	0	20
Sep	11	16	14	42	0	17
Oct	17	25	0	9	0	49
Nov	19	5	10	0	28	38
Dec	0	11	3	5	31	50
1956						
Mar	30	0	1	0	44	25

weight. This increase was partly due to the severe dry season in 1955 which reduced other species by drought and by hard grazing.

Weeds—Regular grazing was probably responsible for the increase in weeds from about 25 per cent of the total fresh weight of the sward in the first year to more than 50 per cent at the end of the second dry season. Of these weeds, about half were broom-weed (*Sida acuta* Burm.), known to the Indians as *chichebe*, whilst *Mimosa* spp. were also common, particularly *M. pudica* L. (sensitive weed).

Discussion

The most striking features about the seasonal yields of this natural pasture are:

(*1*) Only about one fifth of the total annual yield in terms of dry matter is produced in the 5–6 month period from 1 December to the onset of the rains (roughly the end of May).

(*2*) *Tables 1* and *3* indicate that the benefits accruing from applications of phosphate on this particular soil (Barton silty clay loam) [WRIGHT, A. C. S., ROMNEY, D. H., ARBUCKLE, R. H. and VIAL, V. E. *Report* of the British Honduras Land Use Survey Team, 1958. In press] are twofold. Phosphate encourages growth to continue longer at the latter part of the rains in October and November, possibly because of unavailability of soil phosphate when the soil is very wet. Phosphate applications also encourage growth through the dry season.

Table 3. Central Farm 1955 and 1956 dry seasons

Treatment	*No. days in 'dry season'*	*Yield lb d.m./acre*	
		'dry season'	*per day*
No phosphate	170	1 650	9·7
Phosphate	170	2 500	14·7

(*3*) The reduced growth in December is thought to be influenced mainly by low temperatures (mean monthly minimum 60° to 73°F and maximum 74° to 80°F) and short days (the latitude is 17°N).

(*4*) The low production in August is due to the *Maugre* season, characterized by a pronounced decrease in mean monthly rainfall which is accentuated by the evaporation under the influence of the high temperatures prevalent during this month (mean monthly maximum 86° to 91°F and minimum 68° to 81°F).

(*5*) The response to fertilizers is small and somewhat variable.

(*6*) Taking the daily requirements as 20 lb d.m. per beast, and assuming that 50 per cent of the material clipped is actually eaten by a beast during grazing, the approximate carrying capacities can be put at:

No phosphate, 'dry season'—0·24 beast
No phosphate, 'rainy season'—0·96 beast
Phosphate, 'dry season'—0·37 beast
Phosphate, 'rainy season'—1·18 beast

(*7*) These theoretical carrying capacities are likely to be less in practice due to the unsatisfactory botanical composition of the sward (see *Table 2*). The increase in weeds during the 24-month period of the experiment could

hardly be due to clipping since the cage, with an area of 30 ft^2, occupies only 1/29 of the plot at any one clipping and is moved after each clipping. The weeds which survive grazing in natural pastures such as this are of two types, only the first of which occurred in the experiment:

(*a*) tough perennials which recover after grazing. Broom-weed (*Sida acuta* Burm.) and Sensitive weed (*Mimosa pudica* L.) are the most common. These are very woody and the latter possesses hard prickles which deter a grazing animal.

(*b*) sprouts from the roots of felled forest species. Frequent species encountered are Cojeton (*Thevetia gaumeri* Hemsl.) and Cockspur (*Acacia Cookii* Safford). These are kept down by bush-hogging and cutlassing, and are susceptible to 2,4,5-T at 3 to 4 pints per acre.

(B) MR GALVEZ'S PASTURE (EL CAYO)

Experimental procedure

This pasture had also been gradually developed from forest by grazing and occasional cutlassing. During the experiment it was periodically grazed by cattle. The soil is a shallow crumbly clay overlying soft limestone and consequently susceptible to drought.

Plots were 0·02 acre each and were paired to give average values. Clipping of one cage on each plot was done at the end of each month, and each cage moved to a freshly clipped site elsewhere on the same plot.

The following treatments were used:

C—control

N—100 lb/acre sulphate of ammonia (21 per cent nitrogen) in January 1955, October 1955 and May 1956

P—100 lb/acre triple superphosphate (46 per cent phosphorus pentoxide) in January 1955 and May 1956

L—1 ton/acre soft limestone in December 1955.

The areas beneath the cages were clipped at the end of January 1955 and the first measurements of growth made at the end of February 1955. The

Table 4. Natural pasture—El Cayo. Yield (lb d.m./acre month). February 1955–July 1956

Month	*Treatment*			
	NPL	NL	N	C
Jan 1956	627	862	627	710
Feb 1955, 1956	215	328	335	282
Mar 1955, 1956	34	48	46	55
Apr 1955, 1956	0	0	0	0
May 1955, 1956	0	0	0	0
Jun 1955, 1956	272	138	155	125
Jul 1955, 1956	1 251	963	1 385	1 026
Aug 1955	823	789	518	466
Sep 1955	1 118	904	981	1 058
Oct 1955	1 092	944	1 017	1 128
Nov 1955	1 105	635	706	977
Dec 1955	1 301	1 910	1 902	2 156
Annual total	7 838	7 521	7 672	7 983
% yield in 'rainy season'	85·4	81·7	84·8	85·3

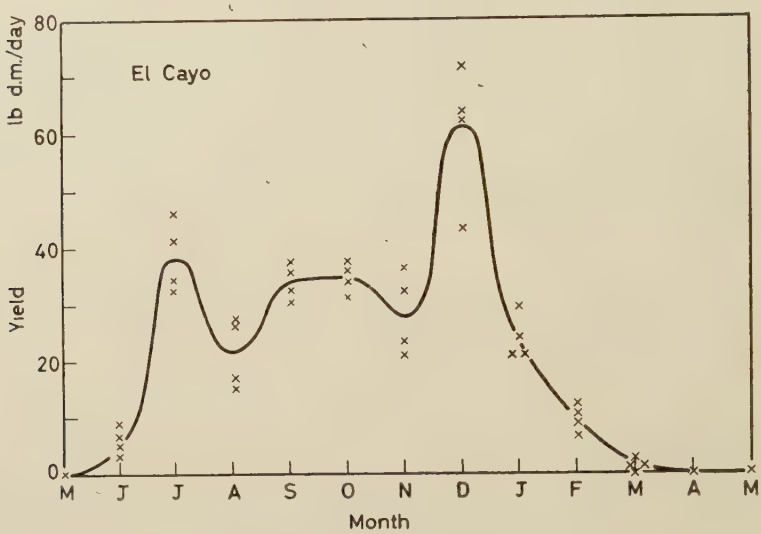

Figure 3. Yield of a natural pasture at El Cayo

trial was discontinued at the end of July 1956, since by then nothing more illuminating was being obtained than confirmation of the information obtained from the Central Farm. Grab samples were taken for dry matter determination and botanical analysis.

Yields

By ' rainy season ' is meant the six months from January to June inclusive.

Yield curves

As with *Figures 1* and *2*, the monthly yield and monthly rainfall data in *Figures 3* and *4* represent the total for that month and are plotted to correspond with the middle of the month.

Botanical analysis

The mean of various botanical analyses of samples taken during the course of the experiment was: *Axonopus compressus* 36 per cent, crab grass 19 per cent, *Paspalum centrale* 14 per cent, *Setaria geniculata* 7 per cent, *chichebe* 7 per cent, and other weeds (by difference) 17 per cent of the fresh weight.

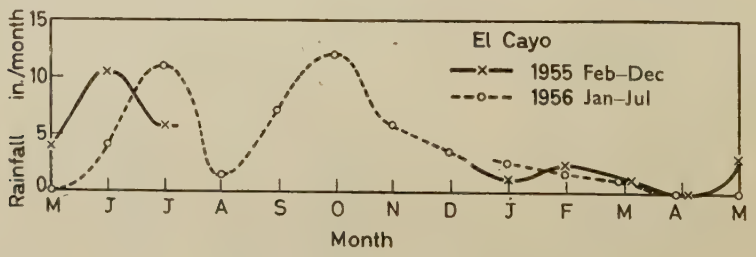

Figure 4. Rainfall at El Cayo

Discussion

The annual growth curve (*Figure 3*) shows characteristics very like those of the curve for the Central Farm pasture (*Figure 1*). Botanical composition of the two pastures was similar. This pasture at El Cayo shows virtually no response to fertilizers, either in the total yield or in seasonal yield.

Taking the daily requirement as 20 lb d.m. per beast, and assuming that 50 per cent of the material clipped is actually eaten by a beast during grazing, the approximate carrying capacities are given in *Table 5*.

Table 5. El Cayo—Carrying capacities, February 1955 to July 1956

Characteristic	*Rainy season*	*Dry season*
Total lb d.m. per acre (mean)	6 537	1 217
lb d.m. per acre per day	36·3	6·7
Carrying capacity (beasts per acre)	0·90	0·17

Chemical analyses

No chemical analyses were carried out during the course of the experiments, but subsequent analyses gave the following values.

Table 6

Natural pasture species (mean of 2 samples)	*% d.m.*	*% crude protein in the fresh material*
Crab grass	51	5·3
Sour grass	43	4·5
Mimosa pudica	73	14·9
Chichebe	89	11·4
Composite weed	35	3·2
For comparison:		
Pangola grass	31	1·9
Jaragua grass	35	2·2
Guinea grass	36	2·6
Sweet grass	31	2·5

The high dry matter content of most of the species in the natural pasture is indicative of a high fibre content and low palatability. These high values for % d.m. cause deceivingly high values for crude protein.

SUMMARY

Data are presented for the monthly yields of dry matter of two natural pastures during 1954, 1955 and 1956. The yields (8 000 to 12 000 lb d.m. per acre per annum) are related to the rainfall but hardly at all to fertilizer treatments. Botanical and limited chemical analyses are also given.

The low yield during the six-month dry season, the poor botanical analysis and negligible response to fertilizers lead one to conclude that such natural pastures give a very low return for outlay on fencing, bush-hogging, fertilizer and water supplies. Further studies are confined to improved grasses properly planted and managed.

ACKNOWLEDGEMENTS

The work here recorded was carried out in the Department of Agriculture, British Honduras, and is published with the permission of the Director of Agriculture. Acknowledgement is made to Messrs V. E. Vial for initiation of and advice upon the work, G. Batty for assistance with the field work, E. Robinson for chemical analyses, and to Mr Galvez for permission to experiment upon his pasture.

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The Effects of Arboricides on East African Trees and Shrubs—IV

Tarchonanthus camphoratus *L. and* Euclea divinorum Hiern.

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The scope of the arboricide work described in this series of articles has already been referred to in the introductions to the earlier papers (Ivens, 1958, 1959). The present paper is concerned with the two tree species *Tarchonanthus camphoratus* L. and *Euclea divinorum* Hiern. which, although unrelated botanically, are similar in presenting very serious bush encroachment problems in the Kenya Highlands.

Tarchonanthus, known locally as *leleshwa*, is a much branched shrub or small tree, growing to a height of about 15 ft and forming almost pure stands on a variety of soil-types at altitudes of 5 000 to 7 000 ft mainly in the Rift Valley, Masai and Nyanza districts of Kenya. The base of the trunk is swollen below ground and produces large numbers of coppice shoots if the main trunk is damaged. The tree is thus well adapted to withstand repeated cutting or burning and can only be successfully cleared if the stumps are dug out. It is thought to have spread over large areas of once open grassland during the last 50 years and is probably still extending its range.

Euclea covers a similar altitude range to *Tarchonanthus* but tends to occur mostly in the higher rainfall areas. Its main natural habitat is dry, evergreen forest where it is often associated with *Olea chrysophylla* and grows into a tree up to 40 ft high. When forest containing *Euclea* is cleared, however, either as a tsetse control measure or to produce grazing, the tree not only coppices but also produces root suckers and the shoots grow with such vigour that after a short time it completely dominates the regeneration. In a few years the regrowth can form dense thickets in whose shade little grass survives and, unless cut back or burnt at frequent intervals, it becomes increasingly dense until the land is useless for grazing.

EXPERIMENTAL METHODS

The experiments described in this paper have mostly been conducted in Kenya, in the boundary area between Masailand and the Sotik district. The chemicals which have been tested the most extensively are 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) and 2,4-D (2,4-dichlorophenoxyacetic acid), while small scale trials have also been carried out with Monuron [N-(4-chlorophenyl)-N′,N′-dimethylurea] and sodium arsenite. The experimental methods employed have already been described (Ivens, 1958), except for the method of applying arsenic. This chemical was made into a

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paste, similar to that recommended by FASSI and MAERTENS (1956), which was spread over the surface of the trunk exposed by ring-barking, as near as possible to the ground.

EXPERIMENTAL RESULTS

(a) *Tarchonanthus camphoratus.* (1) *Standing trees*

Effects of 2,4,5-T and 2,4-D—The earliest trials on *Tarchonanthus* were carried out on trees which had not previously been cut or burnt and so possessed well defined main trunks. Basal sprays of 2,4,5-T and 2,4-D esters were tested, using either diesel oil or water as a diluent, with or without preliminary frilling. In addition, some treatments were tested on freshly cut stumps. Each treatment was applied to a group of 10 trees. In the first trial, concentrations of 1·25 and 2·5 per cent (w/v of acid) were applied in July 1954, when the trees were in flower at the end of the main rainy period. Several treatments killed the majority of the main trunks but after 11 months a considerable number had produced new shoots from just below or above ground level. These regenerating trees were then re-treated with a lower concentration of chemical, the shoots first being cut and the spray applied to those parts of the trunk base from which they arose. In another trial started in June 1955, at a period when the trees were in leaf during a rather dry spell in the rains, lower concentrations were tested and only a single application was made. Details of the concentrations employed and the final results of both trials are shown in *Table 1.*

The treatment which was most effective in killing the above-ground parts of the trees was 2,4,5-T in diesel oil applied with preliminary frilling. In the first trial, concentrations of 1·25 and 2·5 per cent gave a high degree of kill, in the second 1·0 per cent was also effective but 0·5 per cent appeared to be insufficient. 2,4-D applied in the same manner gave a high degree of kill at 2·5 per cent but was less effective at 1·25 per cent. Without frilling, 2,4,5-T in oil killed somewhat smaller numbers and, applied as an emulsion, very few trees were affected.

Even with the most effective treatment only about half of the trees were killed without producing regrowth though the number of shoots appearing from sprayed trees was only of the order of ten per cent of the number growing from trees frilled without spraying. A relatively small amount of chemical applied as a repeat spray appeared to be sufficient to kill the bark at the base of these shoots and to prevent any further regrowth. Thus, with an initial spray of 2,4,5-T in oil at 1·25 or 2·5 per cent applied to frilled trees, followed by re-treatment of the regenerating trees with 0·5 per cent at half the volume per tree, only a small proportion remained capable of continued regrowth after 26 months. 2,4-D at 2·5 per cent followed by re-treatment with 0·5 per cent was of the same order of effectiveness.

Treatments applied to stumps were generally less effective than similar treatments on standing trees and a single spray of 2,4,5-T in oil, although delaying the appearance of regrowth, only caused the death of an occasional stump. An additional treatment with 2,4-D emulsion at 0·5 per cent, however, applied when the regrowth had reached a height of 2 to 3 ft resulted in a moderate kill of stumps after 26 months.

Effects of sodium arsenite and Monuron—In a third trial the effects of 2,4,5-T

Table 1. The results of two experiments with 2,4,5-T and 2,4,-D on Tarchonanthus camphoratus. *In the first trial the regrowth was resprayed 11 months after treatment, in the second trial only a single treatment was applied.*

Months after treatment		*Experiment 1*				*Experiment 2*	
		11 months			*26 months*	*15 months*	
Treatment	*Concentration (% w/v)*	*Number with dead trunk*	*Dead without regrowth*	*Respray*	*Dead without regrowth*	*Number with dead trunk*	*Dead without regrowth*
Standing trees							
2,4,5-T ester							
In oil, frilled	0·5	—	—	—	—	5	1
In oil, frilled	1·0	—	—	—	—	9	3
In oil, frilled	1·25	10	5	*A*	9	—	—
In oil, frilled	2·5	8	4	*A*	8	—	—
In oil, no frill	0·5	—	—	—	—	5	0
In oil, no frill	1·0	—	—	—	—	5	0
In oil, no frill	1·25	7	5	*A*	6	—	—
In oil, no frill	2·5	6	2	*A*	6	—	—
In water, frilled	1·25	0	0	—	0	—	—
In water, frilled	2·5	2	1	—	1	—	—
2,4-D ester							
In oil, frilled	1·25	5	3	*B*	3	—	—
In oil, frilled	2·5	8	6	*B*	8	—	—
In oil, no frill	0·5	—	—	—	—	4	0
In oil, no frill	1·0	—	—	—	—	5	1
Stumps							
2,4,5-T ester							
In oil	1·25	—	1	*C*	6	—	—
In oil	2·5	—	0	*C*	5	—	—
Control, untreated		—	0	—	0	—	—
Respray after 11 months		*A denotes 2,4,5-T in oil 0·5%* *B denotes 2,4-D in oil 0·5%* *C denotes 2,4-D in water 0·5%*					
No. of trees per treatment		10				10	
Vol. of spray per tree		200 *ml* (*respray* 100 *ml*)				200 *ml*	
Mean basal diameter		6·4 *in.*				6 *in.*	
Estimated trees per acre		200				200	
Vol. of spray per acre		9 *gall*				9 *gall*	
Chemical per acre at 1%		0·9 *lb*				0·9 *lb*	

and 2,4-D at a concentration of 1·5 per cent in diesel oil applied to frilled trees were compared with those of sodium arsenite, applied as a 40 per cent paste to ring-barked trunks, and Monuron, sprayed on the ground in a ring round the base of the trees at a rate of 18 g of active material per tree (equivalent to approximately 8 lb/acre). The treatments were applied to trees in full leaf at the beginning of the dry season.

The effects of 2,4,5-T and 2,4-D in this experiment were very similar to those described above. The majority of the above-ground parts of the trees were killed, a somewhat higher proportion with 2,4,5-T than with 2,4-D, but a considerable number (approximately 50 per cent) produced regrowth

during the next 12 months. The arsenic paste was still more effective on the above-ground parts and all the treated trunks were killed, but regrowth was not prevented. A greater proportion of trees regenerated, in fact, and the shoots developed closer to the treated zone than with either 2,4,5-T or 2,4-D treatment.

With Monuron, the foliage of the treated trees started to become discoloured after 2 months and several trees were almost completely defoliated after 6 months. The final effect after 12 months was that the above-ground parts of 60 per cent of the trees were almost entirely dead, 20 per cent appeared entirely unaffected and 20 per cent were partially killed. No basal regrowth occurred with the Monuron treatment.

(2) *Regenerating stumps*

It has already been shown that some degree of kill of *Tarchonanthus* stumps can be obtained with 2,4,5-T or 2,4-D if the stumps are those of trees which have not previously been cut. With trees whose main stem has been cut or burnt at an earlier date, however, control appears to be more difficult. Such trees develop into a mass of regenerating shoots covering an area 3 to 6 ft across and the shoots appear to increase in numbers the more often they are cut or burnt. In most localities where *Tarchonanthus* is encroaching on grassland, attempts at clearing have been made at some time in the past so that it is the regenerating-stump type of growth which is mostly encountered especially in the better grazing areas.

The results of one trial designed to test the effects of repeated applications of 2,4,5-T and 2,4-D on regenerating stumps are shown in *Table 2*. The area had originally been cut in January 1955 and an attempt made to burn the stumps in March. Possibly a few had been killed but the vast majority bore rapidly growing regeneration up to 6 ft high at the time of the first spray treatment in 1956. In view of the woody nature and densely crowded growth of the regeneration, overall sprays were not tested but the regrowth was cut back as low as possible and diesel oil solutions of 2,4,5-T and 2,4-D were applied to the stumps. Treatment of the lower part of the shoots without cutting was also tested as, although a very laborious operation unlikely to be practicable on a large scale, it was thought to offer the best hope of successful control.

The results given in *Table 2* show that neither 2,4,5-T at concentrations of 0·5 and 1·0 per cent nor 2,4-D at 1·0 per cent were very effective and that, only two months after spraying, regrowth had developed with at least 75 per cent of the stumps. Basal spraying with 1·0 per cent 2,4,5-T appeared somewhat more effective for a time and after two months much of the treated growth was dying back. There were few stumps where all shoots were killed, however, and the final proportion of stumps completely killed was only 10 per cent.

The regrowth on the sprayed plots was re-treated in February 1957 when the shoots were 2 to 3 ft high and growing rapidly but, although these shoots were readily killed by an overall spray of 2,4,5-T in water or by diesel oil solutions of 2,4,5-T or 2,4-D applied at their base, they were soon replaced by further regrowth so that six months later at least 90 per cent of the stumps were still alive on all plots. In August 1957 the plot which had twice received

1·0 per cent 2,4,5-T in oil was sub-divided into four and various sprays applied as a third treatment when the new crop of shoots had reached a height of about 4 ft. A third time the shoots were killed back, either by an overall spray in water or by oil solutions applied at the base, but once more the majority of the stumps were able to produce fresh shoots after a few months. As shown in the table the highest permanent kill six months after the last treatment was 22 per cent, the result of three applications of 2,4,5-T in oil at 1·0 per cent. On this plot, as on most of the others, in addition to killing a small number of stumps, repeated spraying greatly reduced the number of shoots produced as well as their vigour. There seems little doubt, however, that even where the regeneration had been reduced to one or two shoots it would have extended rapidly again as soon as control measures were discontinued.

Table 2. The effect of repeated treatment with 2,4,5-T and 2,4-D esters on regenerating stumps of Tarchonanthus camphoratus

Months after first treatment		*2*	*2*	*8*	*8*	*14*
Treatment 1 December 1956	*Number*	*Per cent without regrowth*	*Treatment 2 February 1957*	*Per cent without regrowth*	*Treatment 3 August 1957*	*Per cent without regrowth*
2,4,5-T 0·5% in oil to stumps	138	25	*2,4,5-T 0·2% in water to foliage*	2	*None*	2
2,4,5-T 1·0% in oil to stumps	126	10	*2,4,5-T 1·0% in oil to stumps*	6	*2,4,5-T 1·0% in oil to stumps*	22
					2,4,5-T 0·5% in oil to stumps	21
					2,4-D 1·0% in oil to stumps	6
					2,4,5-T 0·2% in water to foliage	8
2,4-D 1·0% in oil to stumps	65	9	*2,4-D 1·0% in oil to stumps*	9	*None*	8
2,4,5-T 1·0% in oil as basal treatment	111	—	*None*	10	*None*	10
Control, not sprayed	83	0	*None*	0	*None*	0
Size of plot		0·7 *acre*				
Vol. of spray per stump		185 *ml*				
Stumps per acre		160				
Vol. of spray per acre		6·5 *gall*				
Chemical per acre at 1·0%		0·65 *lb*				

(b) *Euclea divinorum.* (1) *Standing trees*

Although the *Euclea* problem mainly concerns regrowth and mature trees occur in undisturbed forest rather than in grassland, there are some situations where a regeneration-inhibiting treatment applied at the time of clearing would be of great value. This is particularly so in parts of southwest Kenya

where large areas of forest containing *Euclea* are being cleared as a tsetse control measure. A trial to test the possibility of killing mature trees and preventing regeneration was therefore started in July 1954 in an area of 'cedar' (*Juniperus procera*) forest where *Euclea* trees 30 to 40 ft high formed a large proportion of the dense, middle layer of the canopy.

Although not previously cut, most of the trees had several trunks, five or six per tree not being uncommon, and the treatments were applied to all the trunks of each tree. The materials tested in diesel oil solution as basal sprays applied to frilled trunks were butyl esters of 2,4,5-T and 2,4-D and a low-volatile ester formulation of a 2:1 2,4-D/2,4,5-T mixture (Weedone Brushkiller 64), all at concentrations of 2·0 and 5·0 per cent (w/v) acid equivalent. In addition, 2,4,5-T in oil was also tested on unfrilled trees and as an emulsion in water on frilled trunks. Other details of the trial are given in *Table 3*.

Table 3. The effects of various arboricides applied as basal-bark sprays to mature Euclea divinorum

Time after treatment	*14 months*		
Treatment	*Number with dead trunk*	*Number probably dying*	*Number with regrowth*
1. *Control*	0	0	6
2. *Frilled only*	0	0	10
2,4,5-T ester			
3. *In oil, frilled 2%*	1	10	9
4. *In oil, frilled 5%*	4	8	6
5. *In oil, no frill 2%*	1	3	9
6. *In oil, no frill 5%*	2	6	7
7. *In water, frilled 2%*	0	2	10
8. *In water, frilled 5%*	0	2	10
2,4-D/2,4,5-T esters 2:1 mixture			
9. *In oil, frilled 2%*	0	6	8
10. *In oil, frilled 5%*	4	8	9
2,4-D ester			
11. *In oil, frilled 2%*	2	9	5
12. *In oil, frilled 5%*	3	8	5
No. of trees per treatment	10		
Vol. of spray per tree	400 *ml*		
Mean basal diameter	3·0 *trunks each* 5·2 *in.*		
Estimated trees per acre	100		
Vol. of spray per acre	9 *gall*		
Chemical per acre at 2%	1·8 *lb*		

The effects of the treatments developed very slowly. Few signs of damage were noted for several months and the rapid defoliation which has been noted as following basal application of 2,4,5-T with many other tree species did not occur. Defoliation of *Euclea* occurs readily enough if the chemical is actually applied to the foliage and the failure of basal treatment to cause defoliation in this trial suggests that little upward movement of chemical from the point of application took place. After 7 months a certain amount of defoliation had occurred but, even after 14 months, although some of the

smaller trees had died, it was difficult to decide whether the majority would recover or not. With many of the frilled trees the bark above and below the treated zone remained apparently healthy though there was no sign of it growing across the gap. Such trees are included in *Table 3* as ' probably dying ', a supposition strengthened by the fact that, with all the unsprayed frilled trees and most of the trees sprayed with 2,4,5-T in water, the frill had long since completely healed over. On the basis of these data there appear to be no obvious differences between the chemicals or between the concentrations. As found in most previous trials, however, water-based emulsions of 2,4,5-T are much less effective than solutions in diesel oil and frilled trees appear to be somewhat more readily killed than unfrilled.

Although the effect of chemical treatment developed so slowly in this trial regeneration developed rapidly and shoots from below the treated zone had reached a height of up to 2 ft after 7 months. New shoots even appeared round the base of some of the unfrilled controls, possibly as a result of the slashing of the bark which took place when labels were affixed to the trees. There is some suggestion from the data that less regeneration occurred after treatment with 2,4-D than with 2,4,5-T but, even at its lowest, regeneration was 50 per cent and this fact, combined with the very slow response of *Euclea* to basal spraying suggests that the use of chemicals to kill mature trees of this species is impracticable.

(2) *Regenerating stumps*

Trials on *Euclea* after the trees have been felled have been carried out on various stages of regrowth with varying degrees of success. On freshly cut stumps the results have been disappointing. In one trial, for instance, a 2·0 per cent oil solution of 2,4,5-T was applied to the stumps of trees immediately after they had been cut. The treatment was applied in September 1955 to a 0·5 acre plot and, only two months later, 80 per cent of the 98 stumps treated had already produced shoots up to 12 in. high. This result also compares with the report in 1956 (Ivens and Cochrane, 1956) that the regeneration following treatment of freshly cut *Euclea* stumps with 5 and 10 per cent oil solutions of 2,4,5-T was 66 and 54 per cent respectively.

More promising results were obtained on older stumps in a small scale experiment carried out near Nairobi in September 1955 during the dry season. In this trial 2,4-D and 2,4,5-T were compared at concentrations of 1·0 and 2·0 per cent in diesel oil. The treated trees had been felled a year or so previously leaving stumps 1·5 to 2 ft high, which at the time of spraying bore masses of leafy shoots up to 3 ft long. These shoots were cut back and the sprays applied to cover the whole stump, using approximately 150 ml on stumps averaging 4·7 in. in diameter. A year after treatment the controls had grown dense masses of regrowth up to 4 ft high while the above-ground parts of the treated stumps were dead and only 10 to 20 per cent had produced new shoots from the base. 2,4-D appeared no less effective than 2,4,5-T. Unfortunately, it was not possible to assess the final results of this trial as the dead stumps provided an attractive source of firewood and many of the labels were lost. After 19 months, however, few traces of regeneration could be located and there appeared to have been a high degree of kill. A treatment of 1·0 per cent 2,4,5-T in oil applied to clumps of root-suckers

growing at a distance from the stumps also appeared to have killed existing growth without stimulating fresh regeneration. The result of treating sucker growth with Monuron, applied as a soil treatment at a rate of 5 lb per acre, was, however, indeterminate. The foliage of the shoots was discoloured and growth was reduced but, even after 19 months, few shoots were completely dead.

In a third trial, which also gave promising results, 2,4,5-T and 2,4-D at concentrations of 1·0 per cent were applied to regeneration appearing a year after the area had been stumped and burnt. Despite the removal of the stumps, clumps of regrowth 4 ft high had developed from the points where the roots had been severed. The chemicals were used both as foliage sprays in water and, in oil, sprayed over the base of the regenerating shoots after cutting back. The treatments were applied in February 1957 during a wet period when rapid growth was taking place and 6 months later, towards the end of the rainy season, very little new growth had appeared. Again 2,4-D was at least as effective as 2,4,5-T. With the oil solutions a few clumps had produced one or two new shoots but, where the water-based sprays were used without cutting, no regrowth had appeared above ground. During the same period untreated clumps had increased in height by 2 to 3 ft or, where cut and not sprayed, had more or less regained their original size.

In this trial also it was impossible to obtain a final result as the area was involved in a fire later in the year and the plot markers were destroyed. The trial was repeated on a larger scale on similar clumps of regeneration in the same district in August, the early part of the dry season, but the results were quite different from those obtained in the first experiment and much less promising. Six months after spraying with 0·5 and 1·0 per cent emulsions or oil solutions of 2,4,5-T or 2,4-D a new development of regeneration had taken place and the clumps of shoots were no smaller than before they were treated.

DISCUSSION

Although the trees discussed in this paper are relatively resistant to arboricides, the experiments on *Tarchonanthus* and *Euclea* help to confirm some of the points brought out in other papers of this series. They show, for example, that diesel oil is more effective than water as a carrier for 2,4,5-T and 2,4-D esters when these are applied as basal-bark treatments and also that frilling helps to increase the degree of kill obtained. With *Tarchonanthus* there is evidence that 2,4,5-T is somewhat more effective than 2,4-D as a basal-bark spray but the difference is not great and, when regrowth is being treated, the two chemicals have very much the same effect on both species.

The great regenerating ability of the two trees means that, to be completely effective, an arboricide must not only kill the above-ground parts but must also reach and affect the centres of regeneration below ground. With *Tarchonanthus* the above-ground parts can be killed relatively easily and, when standing trees are treated, regrowth can also be dealt with. When the trees have been cut and converted into clumps of regenerating shoots, however, although the existing growth is readily killed, it has not been possible to prevent continued regrowth. This may be a result of

the cutting causing an extension of the zone from which new shoots arise or because the absence of a main trunk makes the penetration of the chemical more difficult.

With *Euclea* on the other hand, the above-ground parts appear to be difficult to kill. The response to basal-bark treatment appears to be virtually that of ring-barking rather than of a toxic chemical reaching the leaves via the transpiration stream. As with *Tarchonanthus*, regenerating shoots of *Euclea* are easily killed, but with this species also, it is difficult to prevent the appearance of fresh growth. The fact that regrowth has been delayed for periods of six and twelve months in some trials, however, suggests that under some conditions a certain amount of downward translocation of chemical occurs.

The increased effectiveness of 2,4-D and 2,4,5-T in these trials may be a result of treatment under conditions especially favourable for translocation but is not easy to relate to the time of year at which the application was made. In the trials on shoots appearing after stumping and burning, for example, promising results were obtained after application during the rains and poor results during the early dry season. In another locality, however, the most promising results of all were obtained from treatments applied to old stumps during the dry season. In the trials on *Tarchonanthus* regeneration, there was no evidence of treatments at one time of year being better than others and applications during the early rains (December), middle of rains (February) and the early dry season (August) were all equally ineffective.

It is evident that a great deal more information will have to be obtained on the influence of climatic and soil conditions over the action of chemicals on *Euclea* and *Tarchonanthus* before there can be any hope of developing effective methods of controlling regrowth of these species with 2,4-D and 2,4,5-T. The present trials suggest that, with *Euclea*, the chances are moderately good but that, with *Tarchonanthus*, it is unlikely that a single spray can ever be effective. Repeated application of water-based sprays probably offers the best chance of success but the number of treatments required to exhaust the regenerative powers of the stumps is not known and, in any case, the number it is possible to apply will be strictly limited by economic considerations.

SUMMARY

A series of experiments is described in which the effects of 2,4,5-T and 2,4-D esters have been studied on *Tarchonanthus camphoratus* (known as *leleshwa*) and *Euclea divinorum*, two of the worst woody weeds of grazing land in parts of the Kenya Highlands. Both species are relatively resistant to the action of the chemicals, largely because of their great capacity for regeneration. With *Tarchonanthus*, trees not previously cut were killed by basal application of 2,4,5-T in diesel oil at a concentration of about 1·5 per cent (w/v acid-equivalent) after preliminary frilling (2·5 per cent with 2,4-D) and, although a certain amount of regeneration occurred, a second spray using a lower concentration prevented any further growth.

Trees regenerating after cutting, however, were much more difficult to kill and, although either 2,4,5-T or 2,4-D killed existing shoots, continued

regrowth took place even after the regenerating clumps had been treated three times.

Sodium arsenite paste was no more effective than the growth-regulating chemicals in preventing regeneration. Monuron, although slow acting, appeared to have possibilities as a soil treatment at rates of the order of 18 g per tree.

Mature *Euclea* were only very slowly affected by 2,4,5-T or 2,4-D and regeneration was not prevented. Treatment of regrowth from stumps after cutting, of shoots appearing from the ends of roots exposed by stumping or of root suckers growing at a distance from the main stump resulted in what appeared to be a high degree of kill in some trials but failed to give more than temporary effects in others. There were no obvious differences between the two chemicals on this species and Monuron was less promising than on *Tarchonanthus*.

The season of treatment was not closely correlated with the degree of kill in these trials and it is concluded that, although further work on the influence of time of year on the effectiveness of spraying might be useful with *Euclea*, it is unlikely to produce a simple method of controlling the regrowth of *Tarchonanthus*.

ACKNOWLEDGEMENTS

This series of experiments forms part of a programme of work on the action of arboricides and herbicides under tropical conditions financed by Colonial Development and Welfare funds and directed by the Colonial Pesticides Committee.

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Book Reviews

BANANAS

N. W. Simmonds. Longmans, Green: London, 1959. 466 *pp.* (illus.) 45*s*

We naturally have special pleasure in noticing in *Tropical Agriculture* the appearance of a work by a member of the Imperial College of Tropical Agriculture incorporating the findings of a great deal of I.C.T.A. research. Quite apart from family pride, however, we must hail this latest addition to the publishers' Tropical Agriculture Series as a first-class book on a subject overdue for modern treatment. Mr Simmonds has not only studied bananas intensively as a cytogeneticist over the last 15 years: on expeditions to collect breeding material he has had opportunities to observe banana cultivation and use in East Africa, South-East Asia and the Pacific, and has employed those opportunities to the full. He has thus been able to take a broader view of one of the most important tropical food plants than some previous writers whose experience has been limited more narrowly to the export trade. The interests of the trade, and its problems in production, transport and ripening, do not suffer from being set in proper perspective.

The book is addressed to several classes of readers and, though all can read the whole with profit, different classes will naturally find their primary interest in different chapters. About one third is of special value to botanists, including three chapters on cultivars, which provide the best systematic treatment of the edible bananas ever written and one that (in arrangement at least) is likely to remain the standard for many years. It is good to have at last, in textbook form, a rational classification of banana varieties based on the recognition of two series and of the bispecific origins of the *Eumusa* series. There is a useful key to the group, and copious notes on synonymy help to introduce some element of order into the chaos of varietal names. The amount of work put into this section is faintly indicated by a separate clone index containing nearly 1 000 entries. The botanical chapters include one summarizing the aims, methods and results of banana breeding from 1922 to date.

The other two thirds of the book deal with agriculture, local utilization and the trade, under chapter headings covering climates and soils, planting and management, harvest, transport and ripening, composition and utilization, production and economics, history, pests and diseases. After the wealth of information provided, the most noteworthy feature is the author's critical scientific approach to practical issues. He is not content to describe practices without examining their origins and merits, or to point out differences between local methods without reference to underlying principles. He has, indeed, kept well in mind one of the classes of readers mentioned in his preface—' the planter who may wish to understand why a certain practice is recommended and whether and in what particulars he can safely depart from locally accepted methods of management '. The result is refreshingly different from the general run of agricultural texts.

The avowed aim of the series, to meet the needs of research workers, agricultural advisory officers and planters, would be an impossible one if it meant that each class of reader must enjoy every page. Frankly, some planters at least are likely to skip a few paragraphs here and there, and probably only research workers will appreciate the extremely conscientious acknowledgement of sources. Nevertheless, Mr SIMMONDS gets very near the ideal; and be it noted that he is easy to read as well as erudite. All the classes will get full value for their money, whether they respect the author most for his practical outlook or for his scholarly performance.

The illustrations deserve a word of praise, because anyone who has tried to photograph bananas in the field knows it is not easy to bring out the features wanted. There are nearly a hundred photographs in this book and almost without exception they do make their points. Other features of the production are also up to the publishers' high standard.—E.E.C.

MANUEL D'AGRICULTURE TROPICALE
(Afrique Tropicale et Equatoriale)

M. GAUDY. La Maison Rustique: Paris, 1959. 444 *pp.* (illus.) *Fr.* 3 800

The appearance in any language of a textbook of agriculture for one of the tropical continents is an interesting proposition. M. GAUDY has produced an excellent book; but it is necessary to be clear as to the level of reader for whom it is written. This is not a book for the advanced agronomist; it is designed for educated Africans, such as the staff of the agricultural services. The language is kept clear and simple, with a very moderate use of technical terms; there is no bibliography. The orientation is wholly towards the territories of the French Union in western and equatorial Africa; vernacular words from this region are sometimes used but always explained. The nearest parallel in English is perhaps IRVINE's *West African Agriculture.*

Having said so much, it is necessary to stress that the author has fulfilled his purpose to admiration. Only a reader with more scientific knowledge than those for whom the book is designed will realize how subtly M. GAUDY has boiled down scientific findings into everyday language, and how sound his precepts are. The treatment of all aspects of agricultural production is so comprehensive that the book could almost in itself provide a course of training for senior agricultural instructors. Here and there one could wish for a little more detail, especially perhaps on pests and diseases. But against this there is, as one would expect from the French tradition of agricultural education, an unusually full treatment under that untranslatable heading ' Génie Rurale '—surveying, farm building, road construction and so on.

The book is beautifully produced, with stiff covers, but a smaller size would have been handier than $11 \times 8\frac{1}{2}$ inches.—G.B.M.

IMPROVEMENT OF LIVESTOCK

R. BOGART. Macmillan: New York, 1959. *xx*+436 *pp.* (illus.) $6.75

This textbook would be more adequately titled ' Improvement of Livestock by Breeding ' since only one chapter (' Nutrition and Metabolism

Studies ') is devoted to aspects of improvement of livestock by non-genetic means.

This work is a most admirable elementary treatise on livestock breeding and will be welcomed by all teachers and students of agriculture as filling a notable gap in the literature. It makes for much easier reading than more advanced works, such as LUSH's *Animal Breeding Plans*, and succeeds in the difficult task of making genetic principles seem simple to the non-mathematician.

The author rightly assumes a prior knowledge of biology, including the basic principles of Mendelian genetics. However, at times the results of this assumption are inconsistent. The terms ' homozygous ' and ' heterozygous ' are assumed in the first paragraph of the text, and yet five elementary text figures follow which do not appear to give the reader credit for any prior knowledge of the subject whatsoever. It is felt that the objectives set by the author could have been better served by the addition of a comprehensive ' Glossary of Terms ', which could be referred to by the reader whose basic knowledge is a little shaky.

The author is obviously not a statistician, and most of the statistical formulae given are merely presented at face value, without any derivations or sufficient explanatory memoranda to allow the intelligent reader to follow the basic reasoning involved. This makes for easy reading, and may well be less frightening to the student, but it is clearly insufficient treatment of the important subject of population genetics. A similar fault may be found in certain parts of the actual text. Thus on page 4 the author states that theoretical genetic ratios will only be ' approximately correct' when small numbers of matings are involved. This would appear to infer that, if a penny is tossed four times and comes down heads on each occasion, the resultant ratio of heads to tails is 'approximately 2 heads: 2 tails '. This is stretching the point too far as the author himself emphasizes three pages later in the text.

Certain of the text figures and diagrams are insufficiently labelled for easy reference. Thus the unnumbered diagram at the bottom of page 21 is really a diagrammatic representation of linear scale of phenotypic expression of a genotype. The student reader might well be forgiven for thinking that it was a diagrammatic representation of gene loci on a chromosome.

The text itself reads very smoothly, but the author at times makes undue repetition of certain points. Thus on page 173 we read, ' where there are many genes controlling a character, achievements by selection in each generation will be small, but progress can be made for a longer period of time '. Exactly one page later we read, ' one point that has become clear from this experiment is that where many genes are involved, progress from selection is slow but can be made over a long period of time '. A further waste of space is illustrated on page 160, where the simple sum $0{\cdot}375 \times 1{\cdot}25$ is worked out laboriously, school-boy fashion, in eight lines of type!

On the credit side of the picture, the text really deals with livestock. Illustrations from plant breeding and references to fundamental work on laboratory animals and *Drosophila* are kept down to the minimum. Almost all the major genetic abnormalities of cattle, sheep, pigs and poultry are

described and admirably illustrated. The problems of the commercial breeder, as opposed to the pedigree breeder with large numbers of stock at his command, are sympathetically handled. With a little extra editing, it would be difficult to find fault with this valuable addition to the agriculturist's bookshelves. It is a worthwhile work, whose purchase, even at 6.75 dollars U.S., can be confidently recommended.—P.N.W.

THE WEALTH OF INDIA

A Dictionary of Indian Raw Materials and Industrial Products. Raw Materials, Vol. V: H-K

Council of Scientific and Industrial Research: New Delhi, 1959. *xxv*+332+*xii pp.* (illus.) *Rs* 30.00

The Editorial Committee of this fifth volume of *The Wealth of India* and the Council of Scientific and Industrial Research, New Delhi, are to be congratulated on maintaining the high standard of previous volumes. The latest volume marks the completion of the first half of the series, which now has a total of 1 535 pages of text. It is pleasing to note that steps have been taken to expedite further volumes.

Volume V contains 380 entries, including 370 on plant species, seven on animals and three on minerals. There is a 52-page article on Insects and Insect Pests compiled by a team of distinguished Indian entomologists. The plants given the most space are Para rubber, *Hibiscus* spp., sweet potato and *Jasminum* spp. Nearly 15 pages are devoted to iron ores. It is rather surprising to find notes on hedgehogs, moles and shrews. As usual the work is well illustrated and there are 16 full-page colour plates of high quality and 109 text photographs and drawings. We look forward to the publication of further volumes.—J.W.P.

WATER DEFICIENCIES IN EUROPEAN AGRICULTURE: A CLIMATOLOGICAL SURVEY

J. C. J. Mohrmann and J. Kessler. *Publication No. 5.* International Institute for Land Reclamation and Improvement: Wageningen, 1959. 60 *pp.* (illus.) $1.75

At first sight, it would seem that *Tropical Agriculture* is hardly the place in which to review a publication dealing with temperate climates. Much of the material, however, is equally applicable to tropical conditions. Irrigation is becoming more widely practised from year to year, even in so-called 'humid' regions. For example, the authors mention that the area under irrigation in the eastern states of the U.S.A. has increased by 1 700 per cent in the period 1939–57. The increase is less in Europe, and probably even smaller in tropical areas. It is a fact, however, that irrigation pays in many climates. The greatest limiting factor to crop yields is frequently not soil nutrients, pests or diseases. It is the lack of adequate water. The way in which one tells whether any particular area will respond to irrigation, and the results of doing so for the whole of Europe, are the subjects of this well-written pamphlet.

The first 24 pages give details of how the authors have prepared the ten maps which accompany the pamphlet. Data from 287 climatological stations are used to draw maps of average annual maximum precipitation deficit, average annual increase in precipitation deficit in summer months, average annual potential evapotranspiration, etc. The method used to calculate the required values is that of TURC.

The remaining 36 pages comprise descriptions of the maps and conclusions to be drawn from them, 4 appendices, and summaries in English, French, German and Spanish.

Two minor criticisms may be made. Potential evapotranspiration is only the amount of water used by crops *when water supply is non-limiting*. Precipitation deficit (i.e. potential evapotranspiration minus precipitation) is thus only equal to irrigation need when the irrigation water is applied sufficiently frequently to ensure that this condition is met. Although this point is stressed in the text, and although the titles of the maps do not claim to show more than precipitation deficits and other related quantities, a casual reader might misinterpret them. However, in most practical cases, it is probably sufficiently accurate to assume that actual and potential evapotranspiration are equal. The other criticism concerns the pocket provided to hold the maps, which is extremely flimsy.

It may be mentioned, in passing, that the reviewer is at present engaged in preparing similar sets of maps (on a monthly basis) showing similar quantities to those in this pamphlet, but for the islands of the Federated West Indies.—G.W.S.

ANNUAL REPORT 1958

International Institute for Land Reclamation and Improvement: Wageningen, 1959. 57 *pp.* (illus.)

The Institute, which was established in January 1956 and is supported by the Kellogg Foundation and the Netherlands Government, maintains a small staff of specialists and is located together with the Institutes of Land and Water Management and of Soil Survey at Wageningen, Holland.

In addition to a limited amount of physical and bibliographic research, the Institute of Land Reclamation and Improvement acts as a clearing house for the collection and dissemination of information in that field from world-wide sources. As such it may be expected to perform an increasingly valuable and important function.

The *Annual Report for 1958* consists of a seven-page administrative review presented as a central section bolstered each side by a total of four papers that give substance to the publication.

Dr SCHICKELE of the F.A.O. contributes ' The Role of Land and Water Development in World Food and Agricultural Progress ', Mr S. Herweijer, of the Netherlands Government, discusses ' Agrarian Reconstruction in Europe '. The final section is devoted to impressions of two international conferences attended by Institute staff, the first held at the Wageningen International Agricultural Centre in September 1958 being a ' Seminar on Land Development ' and the second, a ' Center on Principles and Policies

of Land Settlement in Asia and the Far East ', convened in Ceylon by the F.A.O. and other bodies during November and December 1958.

It is the latter article, albeit a brief summary, that will be of most interest to workers in the tropical field. Features emerging are that in all countries of the region land settlement is an integral part of national development, that in many cases it is landless people often unfamiliar with agricultural decisions and management who are settled, and that a concomitant requirement to successful settlement is the creation of an efficient extension service. This has proved to be a difficult task but is being solved through the intermediary use of the multiple-purpose worker at village level. On the social side it was considered imperative to develop a ' community ' among the settlers and not stop short at an ' agglomeration of people '.

This *Annual Report* will have accomplished a useful service if it draws attention to the Ceylon conference which attempted to deal constructively with one of the world's major politico-agricultural problems.—R.H.F.

MINOR ELEMENTS AND THEIR EFFECTS ON THE GROWTH AND CHEMICAL COMPOSITION OF HERBAGE PLANTS

R. Dorrington Williams. *Mimeographed Publication No. 1/1959.* Commonwealth Bureau of Pastures and Field Crops. Commonwealth Agricultural Bureaux: Farnham Royal, Bucks. 1959. 68 *pp.* 7*s* 6*d*

' The importance of minor elements in plant and animal nutrition is now generally appreciated, and their intelligent use in the cultivation of herbage plants may make all the difference between success and failure. Nevertheless, the necessity for correct diagnosis before treatment and for careful application cannot be over-emphasized.'

Taking last things first, the above extract from the conclusions explains the purpose of this publication which is essentially a review of the literature. Such reviews are not easy to produce, the difficulty being to strike a balance between too lengthy an exposition of the individual papers and a straight factual summary of the results. With some 350 individual papers listed the author has taken the second alternative.

He includes a table showing the micro-element contents of various herbage species which though useful in itself serves to emphasize how little is known on this matter. A reviewer's delight—to find a misprint; on page 27, in quoting Colwell's work 9 g is used where 9 gamma is intended. —D.B.M.

GEZIRA: A STORY OF DEVELOPMENT IN THE SUDAN

A. Gaitskell. Faber & Faber: London, 1959. 372 *pp.* (illus.) 42*s*

Here is the definitive story of the Gezira scheme from its inception until 1955. The author served it for nearly 30 years, being the last General Manager for the Sudan Plantations Syndicate and the first Chairman of the Sudan Gezira Board; nobody could be better qualified to write such a book. The text is detailed and the story is at times intricate, especially as to financial arrangements. The heavy parts are written with a sufficiency

of scholarship (though ' condomini ' and ' zenophobia ' are linguistic blots); in the lighter, the author occasionally introduces a lyrical note into his prose.

What sort of story is it which is here unfolded in such elaborate detail? One of the great success stories of British agricultural administration in the tropics certainly; and yet there have always been things to criticize in the Gezira, which are not shirked in this book. In fact it disarms criticism by admitting almost all the shortcomings of which the scheme has been accused, and giving convincing historical reasons for the way in which most of them arose. One criticism which has often been made is that sufficient information about this scheme was not available to the general public at a much earlier date—in fact that this book was not written twenty years earlier. But a reading of the book itself dispels this criticism again; for in the nineteen-thirties no one was yet sure that the scheme *was* a success—in fact, many thought it a failure. In 1951 on the other hand, trouble was experienced at the opposite extreme; the tenants' incomes were so high as to give them a false sense of values which could not be maintained.

For those who know the Gezira, this book will evoke stimulating memories. They will find all the main actors in the day-to-day drama mentioned; every aspect of development is dealt with. The book is perhaps strongest on the financial side, as might be expected from the author's personal experience; the irrigation engineer and the agronomist may find their aspects rather barely covered, but much of the agricultural detail is already available in TOTHILL's *Agriculture in the Sudan.*

Mr GAITSKELL considers that the scheme has a ' wider relevance ' and in a final chapter of this title seeks to define what that relevance is. Against this it may be urged that the Gezira scheme emerged out of a unique set of factors, natural and human, among which the characteristics of the Sudanese people are perhaps not the least. But all who wish to praise or to criticize the scheme, to argue its relevance or irrelevance to their own conditions, will hereafter have to have recourse to this book in which its history is so admirably presented.—G.B.M.

OBITUARY

Thomas Godfrey Mason

Thomas Mason received his scientific education at Trinity College, Dublin. His first post was a lectureship taken up after the 1914–18 war at a Canadian Agricultural College. He joined the staff of the Imperial Department of Agriculture for the West Indies in 1920, with headquarters in Bridgetown, Barbados. His early work with this Department concerned cotton-growing in St Vincent. When the Imperial Department was moved to Trinidad in 1922, and was transformed into the West Indian Agricultural College and afterwards into the Imperial College of Tropical Agriculture, Mason became the first Professor of Botany. He did not stay long at the College and left in 1923 to work in Nigeria in the Agricultural Department which at that time was under the directorship of Mr O. T. Faulkner who afterwards became Principal of the College. Nor did he stay long in Nigeria but was soon back in Trinidad as plant physiologist at the Cotton Research Station which had been newly created by the Empire Cotton Growing Corporation and was situated in St Augustine close to the College. It was here that Mason became associated with E. J. Maskell and afterwards with E. Phillis in their now classical investigations into the physiology of cotton. Numerous papers were published by that team during the period 1928–46 in the *Annals of Botany* describing this work which set a high standard by the brilliance of its conception and the originality of its performance. The particular aspects of plant physiology that were studied mainly concerned the transformations and transportation of carbohydrates and mineral nutrients in the cotton plant. The method of experimental procedure employed was unique and consisted of the collection and chemical analysis of samples of leaves, flowers and bolls at regular intervals during the day and night and at different phases of growth of the experimental crop. This procedure involved the training and organization of a large team of field assistants, recruited from local youths, and it was this part of the planning that comprised Mason's particular contribution to the physiological researches. His success as a scientific investigator was subsequently recognized by his election to a Fellowship of the Royal Society.

Mason retired to the private life of a cacao and citrus planter in Trinidad after the Cotton Research Station closed down in 1946. He had previously acquired an estate situated about 10 miles from the Cotton Station which he capably managed until the time of his death, actually living on his property after retirement. He was regarded as a competent and skilful agriculturist by his fellow planters. He regularly attended the meetings of the Agricultural Society of Trinidad and Tobago whose members benefited greatly by his sound judgement and practical opinions.

By nature, Thomas Mason was something of a recluse although by no means unsociable. His open-handed generosity and his readiness to help his colleagues at the Cotton Station and at the College to solve their scientific problems by his penetrating criticism and deductive reasoning were greatly appreciated by them. His characteristically Irish wit, though devastating at times, and his philosophic outlook on life, were endearing features of his attractive but grave personality.

MASON never married nor was he an active member of the local sports clubs although, in his time, he was a fine long-distance runner and a good footballer. His closest relatives in Great Britain are two sisters and a brother, and to them we offer our sympathy. THOMAS MASON was buried on 23 October 1959, in the College cemetery at St Augustine, Trinidad. His influence on the work and reputation of the College will not be forgotten.

Recent Publications

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

Memoirs—Economic Series No. 2: Peasant Farming, 1*s*; No. 3: Readings in Small Scale Farming, 5*s*; No. 4: Clip-Card Accounting on the Farm, 8*s* 4*d*

A Notebook of Tropical Agriculture. 6th ed. rev. and enl. 1957. 12*s* 6*d*

THE REGIONAL RESEARCH CENTRE OF THE BRITISH CARIBBEAN

Reports on Cacao Research—1945–51, 25*s*; 1952, 8*s*; 1953, 10*s* 6*d*; 1954, 12*s* 6*d*; 1955–56, 15*s*

Reprints are available, at varying prices, of articles in these reports, including the Colour-Illustrated Guide to the Diagnosis of Mineral Deficiencies in Cacao, 5*s* plus postage

Soil and Land-Use Surveys (with maps)—

No. 1 Jamaica. Parish of St Catherine 1958, 20*s*

No. 2 British Guiana. The Rupununi Savannas 1958, 15*s*

No. 3 St Vincent. 1958, 25*s*

No. 4 Jamaica. Parish of St Andrew 1959, 12*s* 6*d*

No. 5 British Guiana. The Mahdia Valley, The Bartica Triangle, The Kamarang and Kukui Valleys, A Part of the Upper Mazaruni Valley 1959, 14*s*

No. 6 British Guiana. The Rupununi Savannas (continued). The Intermediate Savannas. General Remarks. 1959, 15*s*.

No. 7 Jamaica. Parish of Clarendon 1959, 20*s*

OTHER PUBLICATIONS

Flora of Trinidad and Tobago. (The early parts were edited by the Department of Agriculture of Trinidad and Tobago but editing has now been taken over by the Botany Department of the Imperial College. The Flora may be obtained from either address.)

Volume I—Ranunculaceae to Araliaceae (8 parts and index), 26*s* 6*d*

Volume II—Rubiaceae to Labiatae (6 parts to date), 23*s* 7½*d*

Further parts are in preparation

These and earlier publications can be obtained from the Library and Publications Department, Imperial College of Tropical Agriculture, Trinidad

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The following books written by members of the staff have recently been published:

Insect Life in the Tropics, by T. W. Kirkpatrick. Longmans, Green: London. 35*s*

Bananas, by N. W. Simmonds. Longmans, Green: London. 45*s*

University of Nottingham Easter Schools in Agricultural Science 1955 - 1958

NUTRITION OF THE LEGUMES

Edited by E. G. HALLSWORTH. *Price 55s.*

The supply of available nitrogen is so commonly a limiting factor in plant growth that the almost unique ability of leguminous plants to draw on atmospheric nitrogen (hence to be largely, if not entirely, independent of soil nitrogen) is of the greatest importance in the developments of economic cropping systems.

Scientists attending this Fifth Easter School reviewed and discussed the considerable advances made in this field of research during recent years. This collection of 24 papers from the 1958 Conference provides an invaluable and stimulating source of new data for those investigating this field of biology.

CONTROL OF PLANT ENVIRONMENT

Edited by J. P. HUDSON, M.Sc., Ph.D. *Price 42s.*

Control of various factors of the plant environment offers a powerful new research tool for the study of growth and yield. This approach offers attractive opportunities in fields of research ranging from fundamental aspects of plant physiology and genetics to applications of immediate importance in plant breeding, agriculture and horticulture.

The wide interest in the field was shown by the attendances at the 1957 Conference of nearly two hundred scientists—physicists, chemists, engineers, biologists, agronomists, agriculturalists, horticulturalists—all with a common interest in environmental control, and all contributing to the vigorous exchange of views evident between such disciplines.

THE GROWTH OF LEAVES

Edited by Professor F. L. MILTHORPE. *Price 40s.*

All aspects of agricultural production are intimately associated with the growth of leaves and the yield ultimately depends on the efficiency of the photosynthetic processes and on the extent of the photosynthetic surface. Agricultural writings, however, reveal much confusion as to the relevant importance of these two components of energy production with, consequently, much misdirected effort in plant breeding, fertilizer and other agronomic programmes. The 1956 School provided a forum for discussion, among specialists in leaf growth and the Proceedings provide tuition, both theoretical and practical for those who are now working in the field.

SOIL ZOOLOGY

Edited by D. K. McE. KEVAN, B.Sc., A.I.C.T.A. *Price 55s.*

The diverse material presented at the 1955 School gave the literature much stimulating new data and introduced fresh techniques. This volume caused much interest at the time of publication. It has since helped to promote the study of soil fauna by indicating some of the problems that exist in this field and the methods by which they may be tackled. It contains a full account of the techniques demonstrated.

Descriptive leaflets are available from the Publishers, Butterworths Scientific Publications, 4 & 5 Bell Yard, Temple Bar, London, W.C.2

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an important house, because it is the home of Bridgelall, his wife Rhonie and their six children—Ramkissoon, Rookmin, Sancherry, Harold Kissoon, Bairan, and Saladeo the baby. It stands on Lot 223 in the Success Housing Scheme, Demerara.

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